Mobility and Transport Connectivity Series

Drones for Development

Overview of Opportunities in Latin America and the Caribbean

WORLD BANK GROUP

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Table of Contents

List of Figures

List of Boxes

Acknowledgments

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AI	Artificial Intelligence
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIF	Global Infrastructure Facility
ICAO	International Civil Aviation Organization
LAC	Latin America and the Caribbean
NDVI	Normalized Difference Vegetation Index
PPIAF	Private Infrastructure Advisory Facility
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
SDGs	Sustainable Development Goals
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UTM	Unmanned Traffic Management
VTOL	Vertical Take-off and Landing
XAG	Largest Agriculture Drone Service Provider

Basic Definitions

This section aims to define basic concepts related to unmanned aircraft systems (UAS). Additional information on the different types of UAS and related operational concepts are provided in annex 1.

Drone: The term *drone*—widely used to refer to any unmanned, remotely piloted vehicle—is used in this report interchangeably with the more precise term *unmanned aircraft system*.

Unmanned Aerial Vehicle (UAV) and **Unmanned Aircraft (UA):** Both terms are used to refer to an aircraft designed to operate autonomously or piloted remotely without a human on board. According to the International Civil Aviation Organization (ICAO), such a vehicle "can be remotely and fully controlled from another place (ground, another aircraft, space) or pre-programmed to conduct its flight without intervention" (ICAO n.d.). This definition refers to the flying object itself and does not include the other system components required for its operation.

Unmanned Aircraft System (UAS): The US Federal Aviation Administration (FAA) defines an unmanned aircraft system as "an unmanned aircraft and the equipment necessary for the safe and efficient operation of that aircraft" (Federal Aviation Administration n.d.). This definition embraces all the elements required to operate the system—the ground-based controller, the communication system between the UA, and the operator. As this is the most comprehensive definition, it will be used primarily in this report.

Remotely Piloted Aircraft (RPA) and **Remotely Piloted Aircraft System (RPAS):** The ICAO explains these terms as subsets of UA and UAS and used to define unmanned aircraft piloted from a pilot station (ICAO 2011). For simplicity, this report prefers the broader terms UAV/UA and UAS.

Unmanned Aircraft Traffic Management (UTM): According to the ICAO, UTM is "a specific aspect of air traffic management which manages UAS operations safely, economically and efficiently through the provision of facilities and a seamless set of services in collaboration with all parties and involving airborne and ground-based functions" (ICAO 2020). UTM can be supported by a UTM system, "provides UTM through the collaborative integration of humans, information, technology, facilities and services, supported by air, ground or space-based communications, navigation and surveillance.

Beyond Visual Line of Sight (BVLOS): This term refers to a mode of operation in which the pilot has no direct visual contact with the UAV and performs its mission without direct observer assistance. It occurs, for example, when drones are used over long distances and the pilot controls them remotely from a control station. In practice, this type of operation involves a high risk of interference in airspace. Such uses in the civilian sector need to be tightly controlled and are prohibited in many countries, notably in the United States, where they have yet to be regulated.

UAS Ecosystem: This report uses the term *ecosystem* to refer broadly to the interconnected network of components, technologies, stakeholders, regulations, end-users, and industries associated with the development, deployment, and use of UAS in a specific country or region.

Executive Summary

In 2021–23, the World Bank conducted regional analytical work under the Support for Unmanned Aircraft Systems (Drones) in Projects and Operations in Latin America and the Caribbean (LAC) (P176634) Advisory Services & Analytics. The work involved in-depth analysis of the development of unmanned aircraft systems (UAS) in 35 countries across LAC, identified key use cases, and provided a map of key domestic market players.

UAS can be defined as aircraft designed to operate autonomously, or aircraft piloted remotely without a human on board, plus the equipment necessary for their safe and efficient operation. This comprehensive definition embraces all aspects of such systems. In popular usage, UAS are often referred to as *drones*. This is an imprecise term that focuses on the remotely piloted vehicle without including the flying systems behind it. Given the widespread acceptance and use of the term, however, *drones* may be used synonymously with *unmanned aircraft systems* in this report.

Innovation in the UAS sector has resulted in a wide variety of models as new applications are developed. Drones are designed for specific purposes and have different capabilities in terms of range, speed, hovering capability, and load-carrying capacity. Sizes and shapes range from tiny drones used for photography, to big cargo drones able to transport loads weighing dozens of kilos. Costs range from a few hundred dollars for small units to several million dollars for systems requiring infrastructure for operation or for systems equipped with high-tech on-board technology. This variety allows for a wide span of uses that, beyond today's widespread recreational use, can provide new technical solutions for many professional applications in the civil domain.

This report intends to give an overview of the stage of UAS development in the region and serve as a guiding document for public sector decision-makers willing to explore the use of this technology. It seeks to answer the following questions:

- What is the overall level of adoption and stage of development of drone technology in LAC?
- What role can regulation play in the development of drones in the region?
- What applications or use cases might be relevant to support development efforts in the region?
- How can LAC governments and the World Bank support the use of UAS to address development challenges and promote their adoption in the region?

It is not intended to provide a detailed economic analysis of specific use cases.

The Potential of Drones to Meet Development Challenges

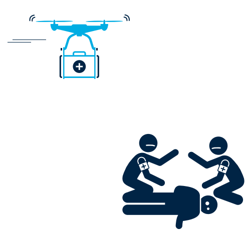
The LAC region faces significant development challenges. This includes limited transport infrastructure, inadequate access to healthcare, threats to biodiversity, and high exposure to natural disasters. Emerging drone technologies could help the region address these issues.

The use of UAS has moved beyond high-income countries and is poised to support development projects in emerging economies. In Africa and LAC, recent use cases of drone applications in health, infrastructure, environmental protection, and agriculture have demonstrated the technology's potential to support development projects.

Regional Overview of the Drone Ecosystem

While drone technology has significant potential across the LAC region, the current stage of development varies widely from country to country. Countries like Brazil, Mexico, and Uruguay present high levels of UAS integration in advanced applications led by the private sector, particularly in sectors like agriculture and mining. Caribbean countries are in the early stages of drone technology adoption, with much of the use associated with recreational activity. Between these extremes, countries demonstrate intermediate levels of UAS adoption, with applications often centered in specific economic sectors. Other countries are in pilot stages and yet to scale up to full deployment.

The private sector typically uses UAS over traditional methods in mining and agribusiness to improve efficiency and reduce costs of certain processes. However, private initiative is not enough to drive the development of UAS in the region. The public sector plays a key role in the definition of regulations, education and awareness, development of initiatives to promote innovation and entrepreneurship, and the mainstreaming of drones as part of public interest projects. This will help drone technology reach its full potential across LAC.



Drivers, Growth, and Barriers for Drone Deployment

Because of its quick response, versatility, and aerial data capabilities, the UAS appears to be a promising technology for LAC countries as they tackle complex problems. Drones can be used to address poor accessibility and connectivity issues by delivering supplies or services where there is little or no access for terrestrial vehicles. They have been used to deliver medical goods, aid, and emergency supplies to remote or inaccessible areas in several countries worldwide (e.g., Rwanda, Ghana, the Dominican Republic, Brazil).

In addition, UAS enables remote observation of disaster management, wildfire detection, and endangered species monitoring, all of which are aided by timely response efforts. They can be used to collect reliable data for urban planning, infrastructure monitoring, traffic management, disaster preparedness, and environmental monitoring. Furthermore, integrating drones into specific use cases can increase efficiency and cost effectiveness (see Chapter 2).

This study identifies five key areas of application for the UAS in World Bank operations. It analyzes 14 case studies to identify relevant areas, key barriers, and specific examples of how UAS offers a comparative advantage over traditional means. From these, five were selected—healthcare, agriculture, disaster risk management, road infrastructure maintenance and monitoring, and habitat restoration and reforestation. These areas are frequently addressed by the Bank and could benefit from additional support. Each case presents a concrete example that demonstrates the benefit of a UAS application and illustrates its relevance to development projects.

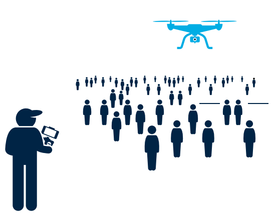
Around 75 percent of the surveyed countries have established some form of specific drone regulation, with varying levels of sophistication. New technologies come with the need to set up regulatory frameworks to define safe use and integration into the public space, and also to allow for growth. The public sector plays a key role in developing regulations for the parameters governing drone operation and for setting the right conditions for innovation to flourish. An overview of LAC revealed that two countries, Brazil and Mexico, stand out as having developed advanced regulations compared to the rest of the region. Most of the other countries (25) are in the early or intermediate stages of developing their drone regulations, which means that the official regulations may be outdated, or less comprehensive, compared to more advanced regulations. A group of eight countries without official regulations consists mostly of small island countries in the Caribbean.

While many countries have begun to develop their regulations, most are not ready for the implementation and use of advanced drone solutions. In many cases, there is a mismatch between the needs of the country and its ecosystem and the existing regulatory framework, the actors, and their capability to comply with regulations. These challenges, along with the limited capacity of regulators to embrace and adapt to the rapidly changing characteristics of the UAS, are some of the main barriers to the development of strong drone ecosystems in LAC.

Despite a significant increase in recreational and commercial use, the expansion of drones in LAC faces certain barriers. These include (i) regulatory limitations and low institutional capacity, (ii) limited funding for innovation, (iii) complexity of the business environment and public procurement systems, (iv) limited public awareness of UAS benefits and potential, and (v) complex import and export requirements for technologies, spare parts, and services.

An Emerging Market with the Potential for Job Creation

The UAS market in LAC is set to grow, but the speed and scale of its development will depend on the policies put in place to facilitate it. The analysis underpinning this study found that if governments implement supportive actions to enable drone usage, the potential market growth over a five-year period would be substantial. The expansion of the drone sector is poised to create hundreds of new jobs in areas such as service provision, software development, research and development, training, education, and more. A projected target scenario estimated that approximately 195,000 jobs could be created in the drone service industry.



Findings and Recommendations

While the development of drone ecosystems can play an important role in addressing LAC's development challenges, creating jobs, and attracting private investment, it is limited by several barriers. In this sense, the public sector plays a crucial role in creating the environment needed for the drone industry to flourish in the region. Consolidating the use of UAS for development in LAC requires increasing public sector involvement in defining innovation policies, establishing solid operational regulations, and developing well-structured UAS projects. The main findings stress the need for public sector leadership in the development and implementation of UAS projects.

The study has revealed valuable lessons and recommendations for advancing the adoption of this technology in the region from a public sector perspective:

- *Holistic approach*. The UAS development strategies should consider various aspects beyond technicalities, like regulatory frameworks, stakeholder awareness, workforce education, digitization, entrepreneurship, governance, and financial sustainability.
- *Tailored regulations*. It is crucial to develop regulations specific to each country's context, balancing safety and innovation in a way that will evolve with the technology and encourage international collaboration.
- *Needs assessment*. The UAS implementation in the public sector should be based on needs assessments that consider drones as tools to enhance existing processes rather than act as standalone solutions.
- *Results frameworks*. Pilot projects should incorporate results frameworks to assess the value of the UAS against traditional methods. Clear metrics and indicators that forecast the solution's potential at full scale and implementation will aid decision-making.
- *Inter-institutional coordination*. Collaboration among public stakeholders in and between institutions is essential for UAS applications. Clear roles and inter-ministerial coordination are necessary to maximize impact and avoid duplication.
- *Capacity building*. Addressing institutional capability gaps is vital. It requires public sector training—in drone operations, and in data processing and analysis—while integrating institutional workflows and mandates.
- *Partnerships*. Partnerships should be established to further enhance the effectiveness of UAS applications. In support of UAS, governments can collaborate with financial institutions, NGOs, the private sector, and academia, all of which will foster knowledge sharing and mutual benefit, showcasing the government's leadership and commitment to innovation.

1

Introduction

Various developmental challenges in LAC can be tackled with one solution: drones. The biggest hurdle drone operators have to face is the lack of clear regulation in the region. Find out how this report can help address these challenges.

1.1. Context: Development Challenges in Latin America

Despite slight progress in the last decade, the Latin America and Caribbean (LAC) region still faces significant development challenges. The regional gross domestic product (GDP) increased by an average of 1.4 percent per year between 2012 and 2022 (including the impact of the COVID-19 pandemic), reflecting modest but positive regional growth.

The region also experienced a slight reduction in its poverty rate from 34 percent to 29 percent over 2011-21.[1] This was accompanied by a slight decrease in inequality, with the Gini index falling from 0.523 to 0.505 over the same period. However, these indicators do not fully reflect the region's heterogeneous reality: major disparities exist in terms of wealth, geographic and demographic distribution, as well as degrees of climate vulnerability.

The region is characterized by both rapid urban sprawl and extremely isolated locations. It continues to be the second most unequal in the world in terms of income, minority rights, and access to public services (UNDP 2021). Against this backdrop, major development challenges remain, including the need to further reduce poverty, address the worrying decline in education levels (OECD 2023a), reduce social inequalities, and build resilience to increasing climate change impacts.

One of the key challenges is the region's transport infrastructure which, despite investment, is hampering development. In most LAC countries, the poor condition of road networks and inadequate provisions for logistics platforms serving ports and airport terminals not only limits territorial development, but also contributes to inequality by limiting access to economic opportunities and essential services. Damage from natural disasters or exposure to adverse weather conditions makes road travel difficult. About 18 percent of the LAC population, or 120 million people, live in rural areas, most of them facing limited or unreliable access to markets and essential services due to poor road maintenance and connectivity (World Bank n.d.; FAO 2019; Sánchez-Galán 2020). Addressing these limitations requires significant resources.

For the continent to meet targets set by the 2030 Sustainable Development Goals (SDGs), it would need to invest nearly US$976 billion, including US$548 billion for new transport infrastructure and US$428 billion for maintenance (Brichetti et al. 2021). Achieving these targets would mean providing all inhabitants with full, year-round access to passable roads within less than two kilometers, and bringing all major cities to the coverage levels of the best-performing cities in the region.

Access to healthcare remains a severe challenge for most countries in the region. In 2020, 25 percent of the population in Latin America and the Caribbean had no access to essential health services (OECD 2021). Timely access to health care and preventive solutions is a significant concern, especially in remote areas with scarce medical supply systems, poor transportation, or high exposure to certain diseases and contaminants. Mosquito-borne diseases plague several countries in the region. República Bolivariana de Venezuela, Guyana, Haiti, and Brazil suffer from exceptionally high rates of malaria, dengue, or Zika, for example. Environmental pollution, deforestation, and extreme climate events (like heavy flooding) may increase in the future and pose additional public health risks. Finally, health crises—like the COVID-19 pandemic in 2020—have impacted the region, challenging health providers to find ways to distribute vaccines effectively while the worldwide health system was under unprecedented stress.

[1] According to World Bank data.

The LAC region also faces complex environmental challenges that have substantial social implications. A hotspot of biodiversity, the region has one of the largest natural capital reserves that covers a range of diverse ecosystems. It plays host to around 40 percent of the world's species and 23 percent of its forests and acts as one of the best bulwarks against greenhouse gas (GHG)–driven climate change and biodiversity loss.

However, this biodiversity is under threat. Unpredictable wildfires and illegal logging and mining are on the rise,[2] devastating vast swathes of the Amazon (De Oliveira et al. 2023), wetlands (like the *Pantanal*), savannahs (like the *Chaco* and *Cerrado*), and coastal rainforests. Meanwhile, poor waste management leads to polluted air, soil, and water, while poaching and other human activities are driving already endangered species to the brink of extinction.[3] Meanwhile, many countries in the region rely heavily on agriculture, both to feed their populations and for export. The region's agriculture sector is critical for global food security and is also a primary source of employment for many local economies. Climate change is leading to decreased yields and rising food prices.[4]

LAC is highly vulnerable to extreme weather and other natural disasters, including earthquakes, hurricanes, floods, tsunamis, and droughts. Climate change exacerbates their frequency and intensity.[5] Between 1970 and 2019, LAC was hit by nearly 2,300 disasters.[6] These events caused 510,000 deaths and damages affecting 297 million people and costing over US$437 billion. Natural disasters have enormous impact on lives and societies; not only do they cause devastating humanitarian crises, but they also wreak havoc on infrastructure, leaving some remote or rural communities completely cut off from vital services. This exacerbates existing problems such as inequality, poverty, malnutrition, poor access to healthcare, and limited access and affordability of essential goods and services.

Continuing efforts to achieve development goals will challenge countries to be more creative and make broader use of new technologies. In a broad regional context of major fiscal constraints and competing development challenges, governments need impactful and more efficient alternatives to continue delivering services to the population. In this sense, innovative solutions can offer new capabilities and possibly generate cost efficiencies, while ensuring adequate and timely coverage for all. Whether they help to simplify processes, reduce operational and administrative costs, or provide a solution to a need that cannot be met by traditional means, new technologies can play a vital role in addressing the region's development challenges. Emerging technologies related to unmanned aircraft systems (UAS), more commonly known as drones, hold particular promise in helping the region address current challenges.

[2] The Monitoring of the Andean Amazon Project (MAAP) reported that in 2022, the Brazilian Amazon lost 1.4 million hectares of primary forest to deforestation, with fires directly impacting an additional 348,824 hectares. This deforestation rose by 20.5 percent from 2021 and was the highest on record since the peak years of 2002–05 (Finer and Mamani 2023).

[3] Data from the International Union for Conservation of Nature (IUCN 2023) shows that in the Colombian Amazon, around 80 percent of the timber sold is extracted from natural forests, posing a threat to one of the most biodiverse areas in the world.

[4] Significant impacts on agriculture in Bolivia and Peru are noted, with changes in temperature and precipitation causing an average reduction of 20 percent in rural incomes in Bolivia, and decreased production of water-intensive staple crops in Peru (ECLAC 2016).

[5] A report by the World Bank indicates that climate-related disasters over the past two decades have cost countries in Latin America and the Caribbean the equivalent of 1.7 percent of a year's GDP. The report projects that up to 5.8 million people could be pushed into extreme poverty in the region by 2030 due to these disasters, with agriculture being particularly hard hit (World Bank 2022).

[6] Centre for Research on the Epidemiology of Disasters—Research center of the University of Louvain, Belgium; and Bárcena 2020.

1.2. The Potential of Drones

Unmanned aircraft systems (UAS) can be defined as aircraft designed to operate autonomously, or be piloted remotely without a human on board, and the equipment necessary for its safe and efficient operation. This definition embraces all the aspects of UAS. In popular usage, UAS are often referred to as *drones*. This is an imprecise term that focuses on the remotely piloted vehicle without including the flying systems behind it. Given the widespread acceptance and use of the term, however, it may be used synonymously with *unmanned aircraft system* in this report.

The increasing rate of innovation in the UAS sector has resulted in a variety of models, sensors, and related technology. Drones are designed for specific purposes and have different capabilities in terms of range, speed, hovering capability, and load-carrying capacity. The sizes and shapes range from tiny drones used for photography, to big cargo drones able to transport loads weighing dozens of kilos. Costs range from a few hundred dollars for small units to several million dollars for systems requiring infrastructure for operation or for systems equipped with high-tech on-board technology. This variety allows for a wide span of uses that can provide new technical solutions for many professional applications in the civil domain.

Driven by a need for innovation to enhance efficiency in several industrial sectors and by the accelerated advancement of the technology, the global market for drones has increased exponentially over the past decade. This rapid growth has seen a proliferation of applications in diverse sectors including construction, utilities, medical goods delivery, environmental monitoring, scientific research, and agriculture. The convergence of UAS development with other fields like imaging, data science, artificial intelligence, and telecommunications has produced a wide variety of solutions with many more to come.

While drone technologies are widely used in high-income countries, they are gaining attention in emerging economies where development projects could benefit from their support—as **demonstrated by recent use cases in Africa**. A recent World Bank study (Stokenberga and Ochoa, 2021) highlights the benefits UAS applications can bring to Africa through a variety of applications such as medical delivery, food aid, agriculture, and infrastructure inspection. This report brings together a wealth of information and specific case studies to better understand the advantages and limitations of UAS. Examples that include responses to humanitarian crises and the delivery of medical products show how UAS projects addressed logistical inefficiencies that would otherwise hinder the timely delivery of medical supplies.[7] This solution integrates established medical supply chains and distribution channels, improving overall logistics efficiency by circumventing the need for an extensive, passable road network. UAS capability to operate in diverse locations, reaching areas where supplies are stored, samples are collected, and where they are used, highlights their adaptability to challenging geographical and infrastructural conditions. In addition, in a various range of applications, UAS can offer cost-efficient advantages over traditional means. This is the case in infrastructure inspection, where the technology can provide more detailed and accurate results at a lower cost than traditional means of road and topographic surveying.

[7] For example, in Rwanda, a drone program that has been in place for several years, allowed to reduce stock-outs to zero and increase the availability of rare blood by 175 percent.

These convincing examples raise the question of how such applications can be boosted to support more innovative and coordinated efforts, especially from the perspective of the public sector, to tackle LAC's development challenges. The development of UAS could support the region's development efforts. Recommended research includes characterizing their level of adoption and typology of application across the region and identifying possible development drivers of and barriers to the use of drones.

1.3. Objectives of this Document

To tackle these questions, in 2021–23 the World Bank conducted regional analytical analysis under the project. Support for Unmanned Aircraft Systems (Drones) in Projects and Operations in LAC (P176634) Advisory Services & Analytics. This in-depth analysis was funded by the Global Infrastructure Facility (GIF) and carried out with the support of the PwC Global Centre of Excellence in Drone Technology. It analyzed the state of development of UAS in thirty-five LAC countries, identified key use cases, and mapped more than 650 main native market players (annex 2 summarizes phases and the methodology of the work). Complementary reports present information in further detail and are available as published deliverables.

The present report is not intended to provide a detailed economic analysis of specific use cases, but rather to outline the degree of UAS development in the region and serve as a guiding document for public sector decision-makers willing to explore the use of this technology. The report seeks to answer these questions:

- What is the overall level of adoption and stage of development of drone technology in LAC?
- What role can regulation play in the regional development of drones?
- What applications or use cases might be relevant to support development efforts in the region?
- How could LAC governments and the World Bank support the use of UAS to address development challenges and promote their adoption in the region?

Without claiming to be exhaustive, this report is intended to provide an overview of the use of UAS in LAC for the public, decision-makers, and development partners to better address the next steps for the deployment of this technology. It also proposes lines of action in this direction and, based on concrete case studies, offers recommendations to guide the next steps.

It is based on primarily comprehensive research conducted from 2021 into 2023. Data sources from those and previous years were used to generate the most accurate picture of the state of the drone ecosystem in LAC and provide best practices as part of international benchmarking. Considering the fast-growing nature of drone technology, its development and the resulting changes, some elements in the report may have evolved since the main analysis was conducted.

2

UAS as a Development Tool for LAC

Countries in LAC cannot have blanket regulations for drone use, primarily because each one is at a different stage of development. However, the untapped potential of unmanned aircraft systems are being explored and milestones are being crossed. So, what is limiting their use in the region?

2.1. Regional Overview: Diverse Stages of Development

The adoption of unmanned aircraft systems (UAS) in Latin America and the Caribbean (LAC) varies significantly (see Appendix 2 for details), with some countries embracing the technology rapidly while others progress more slowly. Civilian applications of drone technology began in the early 2000s, gaining momentum with most players entering the scene between 2010 and 2020. The evolution of drone use in the region has transitioned to a more widespread and sector-specific application in recent years.

Figure 2.1 presents the significant development milestones in the region. Each subregion, including North America, South America, Central America, and the Caribbean, presents a unique set of challenges, constraints, and opportunities. Similarly, drone ecosystems and the political, economic, and social landscapes also vary significantly across subregions.

Figure 2.1. Timeline of Key Drone-Related Events in Latin America and the Caribbean

Source: PwC 2023.

Timeline with Key Drone-Related Events in LAC (Cont.)

2015

BRAZIL
Public consultation of proposed drone regulations

ARGENTINA
First civilian drone for agricultural use developed

2016

BRAZIL
Country's first Unmanned Traffic Management system launched

URUGUAY
First drone services provided for power & utilities sector

PARAGUAY
Tech Guarani conducted region's first 3D printing drone pilot project

2017

LAC LATIN AMERICA
70% of countries introduced drone regulations

PARAGUAY
Drone project to increase reproductive rate of livestock launched

VENEZUELA
Maxdrone certified by INAC as specialized training centre for drones

2018

BRAZIL
Identified as the world's tenth-largest market for agricultural drones

COLOMBIA
First edition of Colombia Drone Expo held

2019

MEXICO
Tijuana and Mexico City launched drone programs in partnership with Cape

2020

MEXICO
Los Amigos Tulum conducted pilot project for passenger drone transportation

BRAZIL
iFood and Speedbird Aero partnered to pilot drone-based delivery

URUGUAY
Dronfies built open-source UTM System for authorization and airspace access for professional drone operations

2021

BRAZIL
Claro signed an agreement for drone-based delivery with 4G and 5G networks

COLOMBIA
Interrapidismo started a program to be the first courier using drones in the country

2022

URUGUAY
Drone.uy received first commercial authorisation of drone cargo flights

CHILE
First light show with 200 drones was held in the country

Source: PwC 2023.

The drone ecosystem can be defined as the interconnected network of components, technologies, stakeholders, regulations, end-users, and industries associated with the development, deployment, and use of UAS. Given the dynamic and evolving nature of the technology and its ecosystem, the assessment conducted in the LAC region provides a snapshot of the level of development for technological advancements, regulatory frameworks, market demands, and emerging applications in the sector. Therefore, in evaluating the degree of development, the analysis also encompasses a mapping and assessment of the development level of regulatory bodies, aviation authorities, service providers, hardware and software manufacturers, education and training institutions, associations, innovation hubs, and end users from public, international, and private sectors, among other relevant stakeholders (see Appendices 4 and 6).

Although the regional and national drone ecosystems, driven by both local and international players and trends, have undergone substantial transformation in recent decades, these changes vary substantially from country to country. Each of the 35 countries analyzed in LAC is at different stages of its UAS ecosystem development. The spectrum ranges from countries like Nicaragua, where drones are banned entirely, to Barbados, where drone use is restricted, to countries like Brazil that have fully embraced the technology and have reached more advanced levels of development.

Brazil, along with Mexico, and Uruguay, are the most advanced countries in terms of UAS integration. Brazil leads the region because of its large local market, especially for agricultural applications, and because of its well-established drone regulations. Led by the private sector, the country has high adoption rates of UAS solutions and has highly accessible technology owing to the presence of many international players and a broad range of local manufacturers. Mexico's UAS ecosystem can be classified as intermediate. The country's market for UAS services has shown consistent growth and companies involved with the agriculture, construction, energy, mining, and security sectors have already implemented the technology, including data science and AI solutions, into their daily activities. Uruguay has a comparatively high level of UAS ecosystem development with a wide range of ongoing drone projects in different industries—agriculture, safety and security, infrastructure—and strong initiatives supporting and financing the drone industry, which will influence the expansion of the drone ecosystem.

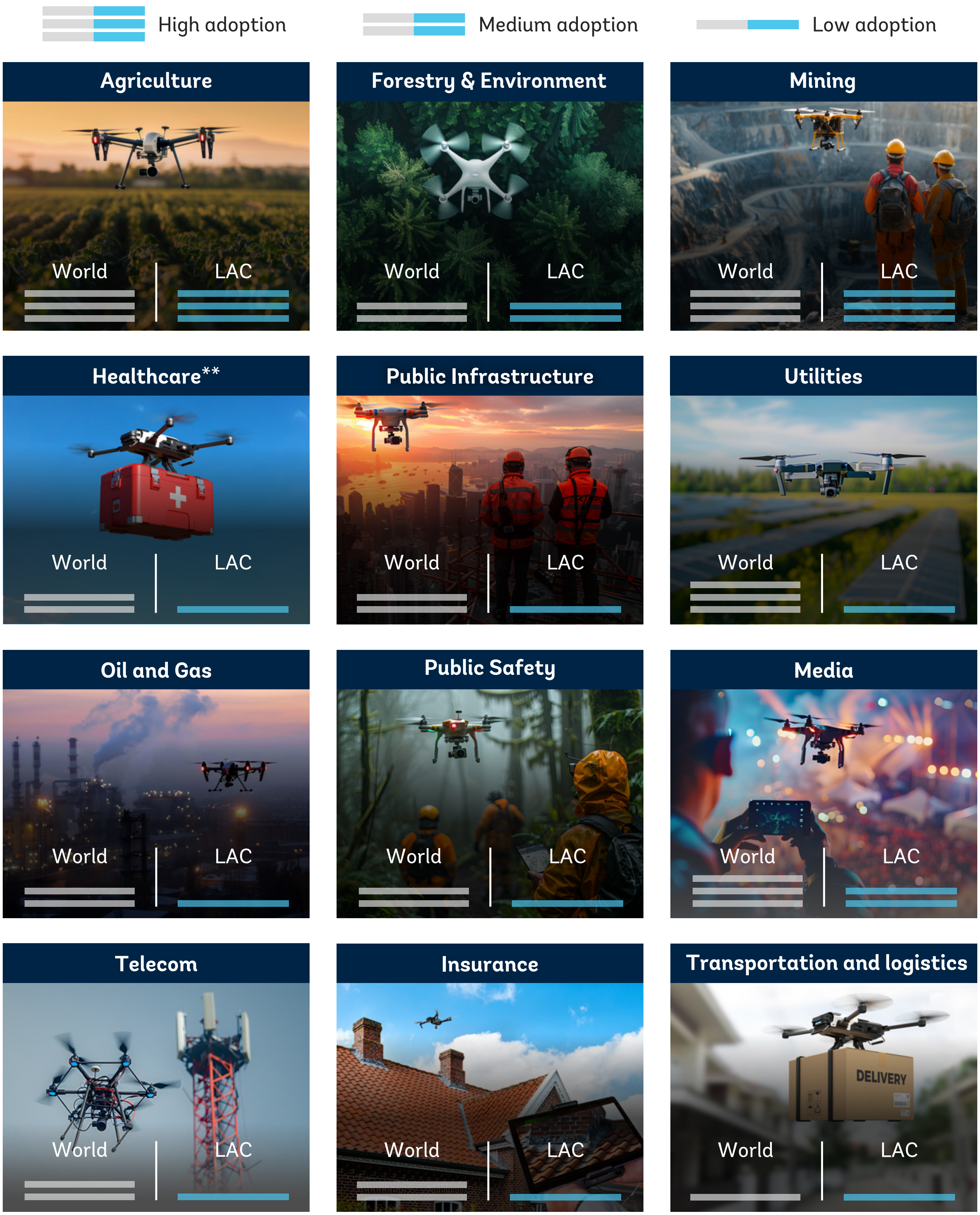
In contrast, Caribbean countries are lagging behind in UAS integration. The region's drone ecosystem is in the early stages of development when it comes to adoption of the technology. Although local drone service providers and technology resellers are present in the countries, local hardware manufacturers and software developers have not been identified. At present, most usage continues to be associated with recreational activities. UAS operators in the Caribbean are primarily divided into two main categories: those originating and operating in Caribbean countries, and those from outside of the region that operate in at least one Caribbean country. International UAS operators are typically contracted over a specified period for disaster relief efforts and community or environmental development. However, there is a clear upward trend in drone awareness and adoption across the 15 Caribbean countries analyzed in this report.

Between the extremes, some countries demonstrate intermediate levels of UAS application, often in pilot stages, and not yet scaled for full deployment. The drone ecosystems of the seven countries in Central America and the Dominican Republic covered in this report are characterized as being in early-stage development, while Panama and Guatemala are leaders in drone technology adoption. In these countries, different use cases have been implemented, some permanently, but most often as pilot projects rather than as full-scale applications. In addition, the regulatory environment does not yet allow for more complex and nuanced drone use cases. Lastly, the user demand and awareness of drones is still at an early stage with lots of potential for growth. In South America, Colombia's drone ecosystem has seen accelerated growth over the last five years and is seeing relevant progress in its technological development. The potential lies in expanding the current drone regulations to enable more advanced use cases. The governments of Argentina, Bolivia, Chile, Ecuador, Guyana, Paraguay, Peru, and Venezuela have all managed to establish official regulations that are quite comprehensive. Although the drone ecosystems in these countries are at an intermediate level of maturity, the regulations are expanding to allow for more advanced use cases.

The integration of drone technology in LAC is primarily driven by private sector ventures, particularly in agriculture and mining. This report presents the results of an assessment of UAS adoption levels across 12 key economic sectors in 35 countries, evaluating the experience with drones and the use of drone technology. The evaluation framework classifies sectors into three categories: high adoption, characterized by widespread use; medium adoption, where drone technology is in experimental or pilot phases; and low adoption, indicating scant evidence of broader implementation in the LAC region.

By aggregating these findings at a regional level and benchmarking them against the most advanced countries using drone technology, this analysis provides a comprehensive overview of the LAC region's position in comparison to global best practices. Figure 2.2 summarizes these observations, emphasizing agriculture and mining as sectors demonstrating the highest levels of drone adoption in the region. Interviews with stakeholders revealed that this trend is primarily fueled by initiatives from private enterprises.

Figure 2.2. Degree to which Common UAS Applications Are Applied across Key Sectors, World and LAC Region



Source: PwC analysis

* global best practices typically in high income countries and emerging markets

** some countries have advanced medical drone transportation systems, but general level of adoption is medium (limited commercial or pilot projects) or low

While studying public and commercial drone end-users in LAC, it was observed that the adoption is much faster in the private sector. In contrast, public sector companies—utilities, for example—display limited awareness and capacity in exploring innovative contractual modalities like public-private partnership schemes for leveraging these technologies to enhance service quality and reliability. This discrepancy typically relates to limited incentives to innovate for state owned companies. At the same time, the private sector invests in technologies that bring a short-term return on investment rather than research and development of new technologies and products.

Countries like the United States, Switzerland, Spain, Poland, and Rwanda, which are at the forefront of developing their drone ecosystems, demonstrate an understanding of the need to advance this area. This includes establishing an institutional capacity to handle drone sector inquiries and creating effective processes, procedures, and IT systems. This is in contrast to the limited drone adoption in the LAC region.

While several LAC countries have started to use UAS for development purposes, there is significant potential for them to scale it up. There are many UAS social and environmental use cases; however, the LAC region presents different levels of development compared to the global outlook. The highest levels of adoption in the region can be found in the agriculture sector—notably in Guatemala, Brazil, Argentina, Ecuador, El Salvador, and Uruguay (Sotomayor, Ramírez, and Martínez, 2021), where pilots for small farmers have been implemented.

The LAC region also uses drones for urban planning (Argentina, Peru, and Mexico have evidence of use); road infrastructure monitoring (mainly in Brazil, Argentina, and Uruguay); and wildfire management (Brazil, Mexico, and Belize). However, they are not yet on par with well-established use cases from around the world. There are some use cases that show great potential despite being in the early stages. Medical delivery is a notable example that is evolving from small scale pilot projects into feasible solutions. This is demonstrated by full-scale deployments in Rwanda, Ghana, and in parts of Nigeria, and by permanent implementation in various urban areas in Brazil over the last few years. Drone applications in the fight against mosquito-borne disease and in disaster mitigation and recovery are also developing use cases. Also gaining traction are several applications for environmental purposes: pollution monitoring in Brazil, Mexico, Peru, Argentina, and Chile; deforestation monitoring in Panama, Brazil, and Costa Rica; and endangered species monitoring in Brazil, Argentina, Mexico, and Belize. Finally, there are a few uses across the LAC region where the applications are being explored on a small scale or in very few countries. These include humanitarian food and aid distribution, waste management and landfill monitoring, remote internet, and road traffic monitoring (piloted in Haiti). Additional information on the use cases is available in complementary reports.

Stakeholder engagement and ecosystem sophistication are central to the transition from the current landscape to the application of drones for development. With multiple stakeholders engaged, the region shows promise, yet the full potential of this technology has not been tapped. The challenge of how to make the applications more effective and scalable is key to leveraging the potential of drones to meet the developmental challenges facing the LAC region.

2.2. The Potential of Drones for Development

The search for sustainable, cost-effective, and innovative solutions to the region's pressing development needs is more important than ever as time runs out to ensure a livable planet. UAS can play a critical role by leveraging their many advantages: speed of response, versatility, and the capability to provide aerial data to help solve complex problems. A detailed list of UAS alternatives and technical characteristics is provided in Appendix 1. Drones can support multiple developmental issues:

- *Address poor accessibility and connectivity.* Drones can provide supplies or services where there is poor or no access for terrestrial vehicles (dense forest, wetlands, mountainous lands and so on). One of the most powerful examples of this is in the delivery of medical goods. UAS have been utilized in multiple countries around the world for the delivery of blood, medicines, vaccines, tests, and samples to and from remote locations and underserved areas. The same model can be used to reach other difficult-to-reach and food-insecure areas like rainforests, wetlands, or islands. It can also be used to distribute food, aid, and emergency supplies to refugees and climate migrants. The use of drones has even been piloted to provide remote internet access in areas of poor connectivity.
- *Allow remote observation where human access is not easy or feasible.* One such use case is in post-disaster management where UAS can provide aerial images of areas that are unsafe or inaccessible due to flooding or landslides, for example. UAS can be deployed rapidly, which is vital when response time can be the difference between life and death. Deployment speed is also key in combating wildfires as drones can help in identifying and extinguishing fires. Another case of remote observation involves endangered species and deforestation monitoring, where discreet surveillance allows wildlife to be monitored with minimal disturbance.
- *Inform decision-makers with an array of rich aerial data in several sectors.* Lack of relevant data is a recurrent issue in LAC, making it difficult for public authorities to make decisions and plan. UAS can facilitate reliable data collection. For instance, in urban planning, such systems can help monitor the growth of unplanned settlements, providing information on current and future needs for infrastructure, utilities, and services. For traffic management and road maintenance, the systems can capture real-time data on congestion and the condition of road infrastructure. For disaster prevention and management, drones help by capturing aerial imagery for the creation of models and slope maps to better assess damages, locate survivors, and inform investment decisions. Drone data are increasingly used for environmental monitoring to provide a wide range of biodiversity metrics in areas of ecological importance like the mangroves in Panama and the Caribbean coral reefs. UAS can also be utilized in waste management to measure landfill mass and ensure compliance.
- *Increase efficiency and cost-effectiveness across several sectors.* Integrated into processes, the systems can improve efficiency and cost-benefit performance. For example, reforestation efficiency is increased, at 25 times the speed of conventional methods (WWF, 2020), and in the fight against mosquito-borne disease, drones can release 50,000 sterile mosquitoes per flight, covering 20 hectares in just 10 minutes (IAEA, 2018).

To more concretely analyze the potential of UAS in the region, this World Bank study included an assessment of 14 different categories of applications where drones can support sustainable development. This assessment of UAS development consisted of identifying actual use cases from the 35 countries. The assessment framework classifies sectors into three categories: *limited or no evidence*, no relevant use case was identified in any of the 35 countries; *testing & piloting*, evidence of a test or pilot project at a limited scale was found in one or more countries; and *mature use case*, at least one case was implemented at a full-scale deployment. These regional findings were benchmarked against countries with the most advanced drone technology following the same approach. This analysis provides a comprehensive overview of the LAC region's use of UAS in development-oriented applications in comparison to global best practices (Figure 2.3).

Figure 2.3. Utilization of UAS for Development Purposes in LAC vs International Best Practices

Social and Humanitarian Problems*

Use case	Level of use case development: World**	Level of use case development: LAC
Healthcare & medical goods delivery	mature use case	testing & piloting stage
Agriculture	mature use case	mature use case
Humanitarian aid	testing & piloting stage	limited or no evidence
Disaster management	testing & piloting stage	testing & piloting stage
Road traffic monitoring	testing & piloting stage	limited or no evidence
Urban planning and monitoring	mature use case	limited or no evidence
Road infrastructure maintenance	mature use case	limited or no evidence
Remote Internet access	testing & piloting stage	limited or no evidence

Environmental Problems*

Use case	Level of use case development: World**	Level of use case development: LAC
Endanger species monitoring	testing & piloting stage	limited or no evidence
Environmental pollution monitoring	testing & piloting stage	testing & piloting stage
Restoration and reforestation	testing & piloting stage	testing & piloting stage
Waste management and landfill monitoring	testing & piloting stage	limited or no evidence
Mosquito-borne disease spread reduction	testing & piloting stage	testing & piloting stage
Wildfires	mature use case	testing & piloting stage

mature use case   testing & piloting stage   limited or no evidence

Source: PwC analysis based on use cases, literature reviews, secondary sources and interviews.
*the level of maturity assigned was based on whether there is an evidence in one or more countries that have achieved full potential of use, and it does not mean that there is the same level of development in each country
**global benchmark countries

The public sector has a key role to play in realizing the full potential of drones for sustainable development applications. As the results of the analysis show, there are few cases of development-oriented applications in the region. The study of public and commercial drone end-users in LAC found that adoption is much faster in the private sector than in the public sector. However, private initiative alone is not enough to drive the development of UAS in the region. The private sector invests primarily in technologies and applications that provide a short-term return on investment rather than in research and development. Without complementary action from the public sector, the development of UAS in LAC may remain limited to applications guaranteeing profitability. Even in LAC countries with the most advanced UAS development, the involvement of public actors has so far been limited by a lack of awareness and capacity to fully grasp the social and environmental benefits that UAS could deliver. The public sector can, however, play a key role in the definition and implementation of policies that promote the use of drones. The voice of the public sector can impact the definition of regulations, the education and development of awareness, and the inclusion of drones as part of public interest projects where benefits, other than purely financial ones, are justified.

2.3. Barriers to the Expansion of UAS in LAC

While there is strong private sector interest pushing the adoption of drone technology forward, the realization of the full potential is impacted by the involvement of the public sector, specifically in removing existing barriers. Some of the most pressing challenges were identified in this study. The following obstacles were often mentioned by stakeholders and highlighted in different articles and studies of the innovation ecosystem in LAC (TMF Group, 2023; Crunchbase News, 2023; Durand and Pietikäinen, 2022).

- **Limited public awareness of UAS benefits and potential persists in LAC.** Despite the significant increase in their recreational and commercial use, a broader understanding of the potential for drones in addressing pressing social, environmental, and economic challenges remain low throughout the region. There is a critical need for greater comprehension of the benefits, capabilities, adaptability, and long-term vision for the full integration of UAS into various sectors beyond media and other niche applications. Such integration is essential for addressing real problems encountered by decision-makers, public officials, and technicians in fulfilling institutional mandates of the 2030 agenda. This lack of awareness hampers public interest in learning about UAS technology (and any job-related opportunities) and diminishes the involvement of the public sector.

- **Lack of funding for bringing innovation to overcome development challenges.** Within a constrained fiscal space, public involvement in innovative technologies often takes a backseat to more immediate priorities. Funding opportunities are relegated to pilot initiatives typically led and financed by development partners. Despite that, the private sector shows some interest. However, investment in innovative ventures remains limited and leans toward profitable commercial operations rather than social or environmental applications led by public sector entities. Compounding this issue is the region's underdeveloped venture capital ecosystem that offers scant opportunities for startups and technology developers to secure funding. These limitations leave innovators and companies with technological advances struggling to mature and scale, which hinders the region's ability to keep pace with global advancements. Addressing this funding gap is critical to fostering a vibrant innovation ecosystem in the LAC region.

- **Complex business environment and challenging public procurement.** From the perspective of the private sector, initiating an innovative business in many countries in LAC is difficult. There are burdensome regulations, unfavorable tax conditions, limited digitization, and a time-consuming bureaucratic process. In addition, traditional public procurement processes are not designed to promote the adoption of innovations by public services. This disincentivizes current and potential entrepreneurs, limiting their business opportunities.

- **Regulatory limitations and low institutional capacity.** While more than 75 percent of LAC countries have established formal regulations for drone operations, their civil aviation authorities (CAAs) encounter several challenges. Despite their general openness to drone operations and the potential authorization for more advanced uses, many CAAs are underfunded. This financial constraint hinders their ability to stay updated with industry advancements and international regulations, as well as to digitize processes necessary for ensuring safe UAS operations. These limitations also hamper CAAs' institutional capacity to support UAS operators adequately, leading to prolonged wait times for basic procedures like flight approvals and drone registration and for more complex tasks such as airworthiness certificates. Moreover, the presence or absence of a robust regulatory framework often acts as a barrier to the widespread deployment of drone solutions. Currently, many countries need to update their regulatory frameworks to address both present needs and future advancements to foster the growth and development of the industry.

3

Five UAS Use Cases for Development

Drones have proven themselves as vital contributors to the progress of multiple sectors.

The World Bank study examined 14 case studies, identifying for each, an area of relevance, the main barriers, and concrete examples of application enabling the comparative advantage against traditional means. Providing examples of concrete benefits of unmanned aircraft systems (UAS), this report presents the results of the analyses for five key areas of application, characterized by varying degrees of development in the region. These are areas in which the Bank frequently intervenes, and which could, therefore, benefit from additional support through its operations. They are healthcare, agriculture, disaster risk management, road infrastructure maintenance and monitoring, and habitat restoration and reforestation. For each of these, a concrete example of application is presented, highlighting the advantages of UAS.

3.1. Healthcare: UAS for Medical Deliveries and Health Services

3.1.1. How UAS Can Address the Challenges

Limitations of transport infrastructure in the region's remote areas remain a major hindrance to healthcare access and medicine supply. In 2020, according to the Organization for Economic Co-operation and Development (OECD), approximately 16 percent of urban households and 21 percent of rural households in the LAC region could not access healthcare services when needed (OECD and World Bank, 2023). The deficit in transport infrastructure in remote areas hampers access to health centers and limits the possibility of preventive and curative care. Additionally, the local supply of medical goods and diagnostic equipment is limited and a major obstacle for emergency response.

By offering rapid last-mile delivery alternatives of medicines, test samples, and blood bags, drones can help strengthen the medical goods supply chain and improve its speed and efficiency. The systems enable a switch from relying on predicted demands to a model based on actual, just-in-time need, which is capable of adapting to urgent, one-off requests. In this way, UAS can help to make more efficient use of resources and reduce waste due to expiry or loss. A good example of the gains in efficiency is provided by the Zipline company's blood delivery project in Rwanda. Over the period 2016–2021, the project's deployment outside the capital achieved 75 percent of Rwanda's blood bag distribution (Forbes 2021). The project eliminated blood bag losses due to expiration delays; prior to implementation, the loss rate was 7 percent (Umlauf and Burchardt, 2022). By making it possible to reach even the most remote areas in record time, the service cut delivery times in some regions by up to eight times when compared to traditional methods. It also provided jobs and training for the local market.

In terms of costs, UAS can help achieve savings in the last mile of delivery when compared to traditional methods. However, recent evaluations of permanent large-scale UAS applications and pilot projects suggest that these cost savings depend on a number of factors, including geographical characteristics, the type of product to be delivered, the demand, the characteristics of the supply chain system (Stokenberga and Ochoa, 2021) and the potential to scale up operations and optimize the business model according to market regulations and needs. Similarly, diverse studies have shown that the UAS does not completely replace traditional methods but is a relevant complement to the existing supply chain systems (Stokenberga and Ochoa 2021). This may enable the entire supply chain system to switch from relying on predicted demands (PUSH) to a model based on actual, just-in-time needs (PULL) (USAID GHSC-PSM, 2017; Skygrid, 2023).

UAS can help to improve health monitoring and access to diagnosis for the most isolated populations, making it easier to provide preventive care. The ability to pick up and deliver test samples as close to the population as possible helps improve diagnostic services. This can also facilitate the monitoring, management, and treatment of maternal care, children's nutrition, and communicable and non-communicable diseases in remote areas. In this way, drones help strengthen the capacity of rural clinics to provide preventive medicine, to offer better access to information about disease outbreaks and monitor trends in supply and demand.

Because of the many potential benefits, drone delivery has been widely tested around the world for over a decade and is gaining momentum globally. In Africa, for example, what started as pilot projects, resulted in the permanent implementation of large-scale operations like in the case of Zipline in Rwanda, Ghana, and Nigeria (Stokenberga and Ochoa, 2021). In addition, the COVID-19 pandemic significantly accelerated the healthcare sector's willingness to innovate, resulting in the launch of a significant number of complex pilot projects since 2020. Zipline's operation of medical drone deliveries started in Rwanda in 2016 and later expanded to other countries in Africa. Those operations resulted in more than 660,000 commercial deliveries, 11 million vaccine doses delivered, and over 4000 healthcare facilities served (Zipline 2023). Studies based on thousands of delivery flights have shown that the reduction in blood waste could reach 67 percent (in Rwanda's example) as well as result in a significant decrease in carbon emissions from the deliveries—up to 97 percent compared with cars (Zipline 2023).

Although there are no large-scale projects in LAC countries as in Africa, a variety of healthcare delivery projects have been undertaken since the early 2010s and there are cases of permanent implementation in Brazil. In 2012, the first tests were conducted after the devastating earthquake in Haiti, when Matternet, a US-based drone logistics company, conducted one of its first healthcare delivery trials in the country. Along with pilot projects executed later in the Dominican Republic, Colombia, Brazil, Uruguay, and Chile, dedicated research projects were also seen in Mexico and Peru. Separately, the Bahamas tested a fully autonomous UAV flight that could carry key medicines across the open water between the various islands beyond the sight of the operator. As of 2023, the permanent implementation of medical transportation by drones for lab samples and other supplies was fully accelerated in specific urban corridors in Salvador and Rio de Janeiro, two of Brazil's major cities.

Using UAS to deliver medical goods to urban, peri-urban, and remote locations in Latin America and the Caribbean could positively impact the delivery of healthcare supplies, reducing healthcare inequalities for both densely populated low-income areas and isolated places. Despite the potential, over the last decade these projects were typically demonstrations of the use case (see Box 2.1 for an example from the Dominican Republic) rather than being large-scale deployments. In Brazil, over the last few years, private and public[8] sector players have driven a trend to scale up operations and move toward permanent implementation to improve the supply chain between healthcare facilities, labs, and private sector providers in major urban areas (Logweb 2023).

[8] Like the case of FIOCRUZ—a public health foundation in Brazil.

3.1.2. Most Common Business Models

The most common model for the delivery of medical goods in large scale projects is outsourcing–contracting a private company to deliver end-to-end services. Medical delivery is considered an essential service, typically financed by the public sector, and often initially supported by development institutions. The public sector engages private suppliers for multi-year contracts. In the case of the drone delivery service in Rwanda, since 2016, the company Zipline has provided services to the Ministry of Health (MoH) and the Ministry of ICT & Innovation (MINICT) through long-term contracts. The remuneration system is performance-based, that is, it relies on the achievement of targets and indicators.

Although third-party contracting is the most common model for this type of large-scale application, the gradual transfer of operations to the public sector could be an option in the near future. Further analysis of the business case would be required. Private funding could also be tapped for operating expenses under public-private partnerships. The pharmaceutical sector might be particularly interested in this type of approach as an opportunity to reinforce its supply chains as is the case in Brazil. It is important to note that the use of UAS for this type of delivery requires "beyond visual line of sight" (BVLOS) operations. It will therefore be necessary not only to provide the appropriate regulatory framework for such uses, but also to develop all the other ecosystem elements needed to successfully deploy the operations at scale.

Box 3.1. Medicine Delivery Pilot in the Dominican Republic

In 2019, a pilot project was conducted in the Dominican Republic for the delivery of medicines to rural areas. The project focused on using affordable, locally repairable, and locally owned cargo drones to deliver essential medicines to remote health facilities. Funded by Pfizer, the project was implemented by two NGOs: WeRobotics and Dominican Republic Flying Labs.

The challenge in that case was the cost of local transport and the limited number of local transport options, rather than the lack of appropriate infrastructure. When local clinics run out of medicines or cannot test patient samples, patients must travel to the hospital in person. Even if patients can afford it, the long journey to the hospital takes them away from their paid work or family responsibilities and is a deterrent. What's more, a patient's health does not always allow a journey over bumpy, winding roads. In many cases, local medical staff have to arrange the transport of specimens or medical supplies using their own means of transport. Sometimes, there is no other way to help patients.

Conducted between June and July 2019, the pilot project consisted of six weeks of consecutive deliveries in the province of San Juan de la Maguana. A total of 101 UAS flights were carried out from Bohechio Hospital to two separate health facilities, a total of 994 kilometers. Flights were conducted under various weather conditions and operational scenarios. All the deliveries were successful, with no major incidents reported.

The results of the pilot showed that the cost of delivery was approximately $0.40 per km for five drone flights per day, compared to $0.43 per km for land transport (a seven percent cost savings per km). Additional cost savings may be achieved if the number of flights per day increases from five to eight, resulting in 23 percent cost savings per km ($0.33/km drone vs. $0.43/km land). With 26 flights per day, cost per km decreases further to $0.25/km by drone representing a cost saving of 42 percent (Khanal et al., 2020).

From a cost efficiency perspective, these results show a break-even point of five flights per week and, with any increase of that number, the UAS solution becomes more advantageous than traditional transport. As weekly frequency increases, so does this advantage.
This example suggests that the more often deliveries are needed, the more profitable the drone applications will be. Other unquantified impacts like time savings, availability of medical items, and the speed of intervention would need to be added to this analysis to translate into direct effects on patient health.

3.2. Agriculture: Support to Small Farmers

3.2.1. How UAS Can Address the Challenges

The agricultural sector, with its technologically advanced agri-food industries, is vital to Latin America and the Caribbean. In recent decades, as a result of its role in global food security, agriculture in the LAC region has been characterized by strong growth (FAO, 2020a). The region produces food for nearly 1.3 billion people. Agriculture accounts for between 9 and 35 percent of the gross domestic product of the countries in the region and it contributes 25 percent of exports (FAO, n.d.).

The region has a well-developed agro-industrial sector, led by countries that are using smart farming practices and cutting-edge technology to maintain its regional and global competitive edge. Brazil is the most significant net exporter of agricultural goods, both in the region and worldwide. The country has also experienced the fastest growth of net exports, expanding its agricultural trade surplus from US$10 billion in 2000 to US$98.8 billion in 2023, with a large increase in productivity of the large farms. Argentina follows Brazil, with an agricultural net surplus of US$30 billion in 2019,[9] albeit with a much more moderate growth rate over the past 20 years. Other LAC countries with notable agricultural trade surpluses include Mexico (US$10.6 billion), Chile (US$5.4 billion), Peru (US$5.1 billion), Ecuador (US$4.9 billion), Paraguay (US$4.1 billion), and Uruguay (US$3.4 billion) (FAO, 2020a).

The private sector is particularly proactive in using innovation to improve processes and increase profitability, particularly in countries like Brazil, Argentina, Guatemala, and Mexico. In the LAC region, agriculture is one of the main drivers for the adoption of UAS technologies and the sector is one of the most advanced in its use of drones. UAS were very quickly adopted by the sector—Guatemala starting commercial drone operations in 2012—which allowed for significant gains in productivity in activities like seeding, fertilizer spreading, and pesticide spraying. The technology is especially well established in crop spraying, where it has been present for at least a decade in Guatemala, Brazil, and Argentina. The application of precise agriculture data analytics and the use of more advanced technology is mainly used in Brazil (control of plagues, water irrigation control, and so on).

However, the sector is marked by a sharp contrast between an advanced industrial sector with modern, high-performance agri-food industry and, in most isolated areas, local food production that uses rudimentary traditional methods. There are 15 million smallholders and family farmers (OECD and FAO, 2019) that depend on their production and are subject to the vagaries of the harvest. A large proportion of their production is intended for local consumption, but their access to the market is often limited by high transport costs and a lack of infrastructure. While 26 percent of the region's urban population is poor, according to the International Fund for Agricultural Development, 46 percent of the region's rural population lives under the poverty line (IFAD, 2019). This segment of the population, with limited access to roads, are susceptible to natural hazards that climate change will intensify, increasing pressure on them, impacting crop yields, and jeopardizing their food security. According to an Inter-American Development Bank report, most regions of Latin America and the Caribbean will barely meet, or fall below, the critical food supply-demand ratio (Prager et al., 2020). In eastern and central Guatemala, southern Honduras, eastern El Salvador, and parts of Nicaragua, yield reductions of 50–75 percent have been reported, along with a decrease in productivity levels. As a result, more than 2.2 million people in these countries are food insecure, with more than 1.4 million in need of food assistance (WFP, 2021).

[9] In 2023, the surplus was reduced due to the drought affecting Argentina. Higher surplus is expected for 2024 and beyond.

In this context, UAS can offer small farmers numerous advantages compared to the limited resources at their disposal and small farmers and cooperatives can potentially share the cost of drone equipment and services across a wide range of applications. UAS can facilitate crop health monitoring; high-speed fertilizer and pesticide spraying with high levels of accuracy that minimizes chemical exposure; and reduced water use for the applications. Additionally, drone sowing enables seeds to be placed deep into the soil, ensuring protection and germination under optimal conditions.

UAS technology has the potential to address information and access inequality, to help farmers protect their crops, improve yields, and achieve greater profitability. Chemicals are vital in helping farmers protect harvests and livelihoods. Estimates suggest that up to 60 percent of global crops are saved each year by the use of pesticides. In developing countries, farmers rely on backpack sprayers for pesticide application. Drone application can be up to 50 times faster, increasing efficiency while reducing human exposure to chemicals. Also, drones can use as little as 10 percent of the water used by backpack sprayers (Devex, 2019). The accuracy provided by drones ensures less waste and less danger of unintended environmental impact through runoff. Effective crop protection depends on the affordability of the treatment, the accuracy of the application, and the ability of farmers to know when and how to treat their plants. Drones help to identify pest threats more effectively than human surveillance. Early warning of pest activity gives farmers a head start and a chance to save more of their crops. With the use of data, drones are also able to deliver targeted chemical treatment at the optimum place and time to protect crops–smart agriculture. Drones, and the development of precision agriculture, have the potential to positively impact crop yields and quality, food security, environmental sustainability, and financial stability, which will improve the lives of farmers and local communities in the LAC region. With the support of agricultural extension services that present the advantages of the technology, while also providing training, and with the willingness of cooperatives and associations to share the costs of adopting this technology, there is the potential to increase the use of UAS beyond the more productive agri-business models.

3.2.2. Most Common Business Models

Financial support from governments, financial institutions, agricultural input distributors, and extension services can ensure that small farmers and cooperatives, regardless of size, are able to access drone services. Business models to support small producers and expand the adoption of UAS include these approaches:

- *Top-down approach: Public-private partnerships*. The government identifies areas and individual rural communities that need help improving the efficiency of their activities and launches a relevant drone program supported by the existing extension services. Drone companies apply for a program, and selected service providers start the collaboration with local stakeholders.
- *Bottom-up approach: Individual farmers, cooperatives, or associations*. Hardware and software, or professional services, are jointly purchased with combined resources, thereby sharing the cost. Governments can provide subsidies; financial institutions can provide small loans for program costs.
- *Indirect alternative funding from organizations that benefit from increased agricultural output and productivity*. In this model, farmers will get drone services for free or at a significantly reduced cost, for instance:

- Organizations producing and distributing agricultural resources (fertilizers, seeds, pesticides, agricultural equipment, and so on) may pay for and use the data generated by the service provider to demonstrate the need for their products.
- Companies selling fertilizer could simultaneously provide drone spraying services free of charge (or at a small fee) as the fertilizer will be used in a more efficient way. At a large scale, such activity will reduce costs.

Box 3.2. UAS for Small Farmers by Fair Trade Producers of Sugarcane in Four LAC Countries

Toward the end of 2018, the Product-Sugar Coordination at the Latin American and Caribbean Network of Fair-Trade Small Producers and Workers (CLAC) recognized a significant opportunity to bolster technological support by introducing UAS for agricultural monitoring among cooperatives. This initiative also included a component associated with capacity building and knowledge sharing, with the overarching goal of fortifying local capability for the integration of the technology into daily operations. The purpose of this initiative stemmed from the needs of the cooperatives themselves, where the critical lack of precise data for effective preventive management of plantations and the efficient monitoring of crop performance was underscored (CLAC 2022).

Given CLAC's understanding of the transformative potential of UAS in the agricultural sector across LAC, the organization committed to supporting the introduction of the technology as a means to address pertinent issues and drive technological transformation. The pilot aimed to showcase tangible benefits including cost savings, economies of scale, heightened productivity, and enhanced competitiveness in the sector.

Between 2019 and 2022, in response to the concerns and needs expressed by growers, CLAC procured UAS technology and initiated a pilot project to introduce it into sugarcane growers in the Fair-Trade System. The pilot project included 12 agriculture cooperatives and associations from Belize, El Salvador, Costa Rica, and Paraguay where farmers, with an average age above 45 years, had limited to moderate digital knowledge (Ramirez, 2024). The pilot included several phases: identification of beneficiary countries and organizations; resource allocation for technology acquisition; capacity building among beneficiaries; monitoring plans and implementation; analysis; knowledge transfer among cooperatives and across countries; and sustainability of use, decreasing digitization and technology gaps among small-scale farmers.

Given the diverse contexts of implementation across countries and cooperatives, the applications and outcomes of UAS use varied significantly. For example, in Costa Rica, drones facilitated real-time visualization of progress in cutting fronts during the Zafra period, and aerial monitoring for aphid presence in plantations. In El Salvador, unmanned vehicles were beneficial for weed monitoring and control, providing farmers with more time to respond to critical situations. In Belize, the implementation of drones for monitoring activities and making data-driven replanting decisions led to notable savings in time and resources. And in Paraguay, the technology contributed to a reduced carbon footprint in monitoring activities and improved control over sugarcane's proximity to non-organic crops (CLAC, 2023b).

Box 3.2. UAS for Small Farmers by Fair Trade Producers (cont.)

Despite those different applications, the cooperatives stressed that the introduction of UAS technology, the capacity building, and knowledge sharing across entities and growers led to positive results: savings in time and resources in agricultural monitoring processes; greater efficiency in monitoring tasks; increased objectivity in decision making; and the generation of timely and accurate data for decision-making. Additionally, the project increased the level of acceptance among growers for new technologies in agriculture. It also attracted and involved younger generations in the use of UAS.

However, some barriers to the promotion of new technologies in small sugarcane producers were also identified. These included: reactive approaches in determining actions without a comprehensive vision of the entire management processes; resource constraints primarily stemming from traditional skillsets; and the need for enhanced knowledge and upskilling initiatives. Despite these challenges, the implementation of drones in the cooperatives brought significant value, presenting opportunities for scaling up and exploring other applications that might be relevant for farmers. (Drones were later used for crop monitoring during a drought period, which informed decision making around irrigation.) (Fairtrade International, 2021; CLAC, 2023a).

3.3. Monitoring Road Infrastructure

3.3.1. How UAS Can Address the Challenges

Monitoring road infrastructure during planning, construction, and maintenance is fundamental in ensuring the efficiency and long-term viability of these assets. This effort involves continuous investment in maintenance, enhanced road safety, and fortification for climate resilience. The ability to provide essential data to designers to assess the vulnerability of infrastructure, monitor construction progress, and evaluate the condition of roads is crucial for the public sector. Reliable and current information is essential for informed decision making.

In the LAC region, however, resource constraints often interfere with adequate monitoring before and after construction, adversely affecting the sustainability of road infrastructure. Before construction, aerial footage can assess land requirements and the implications of resettlement. Once the work begins, road authorities predominantly depend on conventional reporting methods. These methods yield delayed feedback, often in the form of lengthy and cumbersome reports, with minimal relevant data for timely corrective actions and adjustments to schedule delays. This can be exacerbated by collusion between contractors, suppliers, supervisors, and officials, resulting in inflated expenditures.

In the maintenance phase, the challenge of regularly assessing the condition of road infrastructure using traditional on-site inspection methods is significant. Traditional methods allow for a limited understanding of the condition of the road network and its surroundings, which is insufficient for addressing critical water erosion control. The data is often only available in analog form, thereby complicating effective maintenance programming. The obstacles to getting current data can undermine the utility of digital road asset management systems that rely on updated information.

To address these challenges, UAS present several solutions to enhance the monitoring and maintenance of road infrastructure, often in conjunction with technologies like geographical information system (GIS) or building information modeling (BIM). The application of UAS in this context is multifaceted. It includes time-sensitive land and road surveys, precise mapping for resettlement and monitoring for road distress and disaster vulnerability. All of this allows for the accurate assessment of billed quantities, which significantly reduces errors in overspending, asset inspection, post project documentation, highway infrastructure maintenance, bridge inspection, pavement condition analysis and the right of way monitoring.

UAS imagery offers the precision needed to detect various road and pavement defects such as ruts, potholes, edge failures, raveling, delamination, cracks, bleeding, corrugations, or shoving. Systematically captured drone data facilitates the inspection of road infrastructure for potential damages and issues, including construction cracking due to land movements. This data can be processed into multiple deliverables, such as bare terrain models for mapping road surroundings. Drone imagery is instrumental in creating orthophoto maps that are accurate and detailed. The technology can also generate 3D visual representations of real assets, including post disaster technical shape inspections and quality verification during construction and reconstruction work.

Inspections via UAS present a time- and cost-saving solution that enhances the climate resilience of road infrastructure. In 2019, a study conducted by the American Association of State Highway and Transportation Officials (AASHTO) revealed that the drone inspection of a two-lane freeway bridge in the United States cost US$1,200, whereas a manual inspection would cost US$4,600. The use of drones could potentially reduce costs by 75 percent. Notably, the manual inspection price does not include the expense associated with truck and equipment rentals or user delay costs, which AASHTO estimated to exceed US$14,000 per bridge (AASHTO, 2019; Fenstermaker, 2022). The major cost savings stem from reduced requirements for traffic control and access equipment. Although the cost of inspection specific drones equipped with appropriate imaging devices for basic surveys start from around US$1,000, for more advanced inspections with the addition of payload and batteries, the cost starts from around US$20,000 (DJI n.d.a; n.d.b). The decision and approach to the introduction of UAS for road inspection may vary according to institutional needs, frequency, and workload. In some cases, it may be more cost-effective to own the equipment, while in others, it would be better to hire a third-party provider.

While the adoption of a drone-based approach for inspections is still limited across the LAC region, the technology has been validated and is in use in Uruguay, Brazil, Argentina, and to some extent, in Guatemala and El Salvador. Around the world, road agencies have adopted drone technology for a variety of purposes, integrating it alongside other technologies like mapping vehicles and other surveying techniques. In the LAC region, apart from Brazil's concessions and the National Department for Transport Infrastructure (DNIT), confirmation of widespread use has not yet been achieved.

3.3.2. Most Common Business Models

Depending on the end user's strategy and capabilities, drones may be implemented for road monitoring using one of two recommended business models: hiring commercial services providers, which can be paid according to performance-based conditions, deliverables provided, and accepted billing; or by developing in-house capabilities. The latter supposes an effort in institutional capacity building and may potentially require staff training. Also, concessionaires of roads usually outsource this type of work to service providers, which can be replicated in future models of performance-based contracting for road maintenance.

Box 3.3. Monitoring Road Networks and Critical Spots in Brazil

In 2023, the DNIT started to use drones to monitor the 55,000 kilometers of roadway under their jurisdiction, bid out in three different contracts. The State of Bahia, with the support of the PREMAR 2 project (P147272) and some road concessionaires, is using drones to analyze the right of way, to assess disaster risk on road assets, and evaluate economic benefits of adaptation measures. This has been done by a consultancy called STE from Rio Grande do Sul since 2021. In addition, the World Bank undertook a study called "Improving Climate Resilience of Federal Road Network in Brazil" (World Bank, 2019) during which UAS were tested.

DNIT, Bahia, and road concessionaires use small drones as a low-cost alternative for topographic and georeferenced characterization, right-of-way monitoring, slope control, drainage analysis, and disaster prevention on the road network.

Use of Drones for Right-of-Way Registration Management on Highways in Bahia STE

Serviços Técnicos de Engenharia, in partnership with the innovation laboratory HUBITTAT, uses UAS equipment in services of public agencies. The contract with the Superintendence of Transport Infrastructure of Bahia includes an inventory of the right of way of highways under the jurisdiction of the State, studies, and field inspections to assist in the management, monitoring, and supervision of a network of 11,500 kilometers. Approximately 2300 kilometers that are considered medium and high occupational density are mapped using drones. The use of the technology was based on the varied information from these areas and on the amount of information needed for the inventory: commercial, residential, and public buildings and access points; utilities (electric, communication, gas, fuel networks, and so on); social equipment; visual devices and advertising, among others.

Use of Drones for Environmental Management on Highways in Rio Grande do Sul

The contract with the Empresa Gaúcha de Rodovias (EGR) called for the management and implementation of environmental programs to comply with operating licenses for toll plazas and a road network of 911 kilometers managed by the company.

Box 3.3. Monitoring Road Networks and Critical Spots (cont.)

For the term of these services, the use of drones enabled the mapping of environmental liabilities: containment structures; existing environmental signage; irregular occupations in the right of way areas; locations with improperly disposed solid waste; as well as sensitive areas and critical points for the occurrence of environmental accidents. With this comprehensive and detailed database, it was possible to identify, plan, and carry out the most strategic and effective actions for conservation and environmental management.

Analysis of Climate Vulnerability Points in Rio de Janeiro, BR 101

UAS were used to carry out 3D photogrammetric surveys of the critical points (Figure B3.3.1). The advantage of UAS over traditional topographic surveying methods is their ability to survey many points, which enables accurate 3D modelling of the terrain. Once processed, precise geotechnical analysis is possible, which facilitates the design of engineering solutions. Because the technology is flexible to use compared with traditional methods, regular updates are easier to make. It is then possible to compare data over time and monitor changes.

Figure B3.3.1. 3D Rendering of a Critical Point on the BR-101 Highway

Source: World Bank.

The test, carried out on the three points, confirmed the practical value of this type of survey. The quality of the data obtained, both in terms of density and precision, surpassed traditional means of monitoring.

Box 3.3 Monitoring Road Networks and Critical Spots (cont.)

The experience also highlighted the cost-benefit ratio of the solution, emphasizing low investment, fast data processing, reduced analysis team requirements, and consistent results. Extrapolating the cost of this pilot, **it can be estimated that under the assumption of an outsourced service, the linear cost to produce this kind of information in Brazil could be around US$350 per kilometer** (considering a 60-meter-wide strip).[10] The overall cost includes the price of topographical surveys and data processing. Drones provide a cost-effective and efficient solution for topographical surveying and data processing by significantly reducing the need for expensive equipment and labor compared to traditional methods. The ability to rapidly cover large areas with minimal manpower not only accelerates project timelines, but also leads to considerable cost savings and increased productivity making drones a superior choice for modern surveying needs (Discount PDH.com, n.d.).

3.4. Reforestation and Environmental Monitoring

3.4.1. How UAS Can Address the Challenges

The LAC region faces significant challenges in forest conservation, marked by historic losses–4.5 million hectares lost in the 1990s and 2.2 million hectares lost between 2010–15. The region experiences severe consequences from large-scale deforestation due to wildfires, droughts, and floods. All are exacerbated by climate change, which hinders forest recovery and impedes efforts to combat illegal logging (FAO, 2018). A bleak forecast predicts that the confluence of climate change, ongoing deforestation, and fires could lead to a 60 percent loss of the Amazon Basin's forest by 2050 (Mongabay, 2009).

Home to the world's largest tropical forest area, the LAC region grapples with diverse socioeconomic drivers that threaten its forests: urbanization, agriculture, and beef production. According to the Food and Agriculture Organization of the United Nations (FAO, 2020b), in 2010–20, South America lost an average of 2.6 million hectares of forest per year and this rate appears to be increasing. Between 2018 and 2019 alone, the rate of tree cover loss in the LAC region increased by 2.8 percent (Mongabay, 2020). The Amazon Forest, once an enormous carbon sink, has transformed into a carbon source, emitting a billion tons of CO_2 annually due to illicit forest fires for agricultural purposes (mainly beef production), adversely affecting indigenous communities reliant on the rainforest (The Guardian, 2021; Greenly, 2023). These destructive activities impact local tribes that depend on the rainforest for growing and gathering food, hunting, and fishing.

In the case of the LAC region, it is crucial not only to restore forests such as the Amazon jungle, but pay attention to the mangroves, savannahs, (Chaco, Cerrado), and coastal rainforests, all of which are among the world's most endangered and critical ecosystems. Mangrove forests provide coastal protection from storm surges, maintain climate, control floods, stabilize the coastline,

[10] This estimate is based on the information provided in the report and assumes an average conversion rate of 1 R$ (Brazilian Real) = 0.25 US$ for the year 2019 (https://www.exchange-rates.org/).

boost fish stocks, and remarkably store five times more carbon in their soil by surface area than tropical forests. Coastal rainforests in Brazil and Central America are below 5 percent of the historical range and deforestation for soybean production is transforming savannah landscapes all over the region. This extensive deforestation of the LAC region reflects complex political, social, and economic realities. Therefore, governments and local authorities should introduce comprehensive strategies to address key drivers of deforestation and discuss ways of halting the activity. For example, establish frameworks and initiatives that focus on restoration and reforestation technologies.

This technology has made considerable progress around the world recently, with several success stories being reported by independent entities from China, Canada, and Spain. However, reforestation activities using drones have yet to be scaled up in the LAC region. Pilot projects have been performed in countries including Panama, Brazil, and Costa Rica. Brazil was probably the first country to start research and development around the use of drones for reforestation purposes and has been using it since 2016 for diverse biomes (the coastal rainforests in São Paulo and Rio de Janeiro (PwC, 2022b), the Amazon Forest in Mato Grosso, savannah of Cerrado in Piauí).

3.4.2. Most Common Business Models

Restoration or reforestation efforts with UAS are usually in line with national or regional policies and are most often funded and managed by local or central governments with frequent support from development partners. However, given the high environmental stakes involved, alternative funding from NGOs, charities, or crowdfunding is often used. Funding may also be provided by industrial stakeholders from sectors (timber, for example) as part of mitigation requirements for obtaining environmental approvals.

From a technical perspective, such operations require specialized equipment custom-built by hardware manufacturers or researchers. The hardware can be operated by a service provider (which is often the same as the hardware manufacturer) or in-house, after extensive employee training.

The adoption of these technologies by the public sector requires time to test new approaches, assess their effectiveness, and apply changes. And so, there is a need for a long-term strategy with clear responsibilities and milestones for each agency/government unit. It requires significant capacity building and strong inter-institutional coordination between the various ministries involved.

Finally, community involvement in drone reforestation and environmental monitoring is a key element. A good example of this is the work carried out by the WWF in Brazil, where indigenous communities have been trained in the use of dedicated technologies, including drones to monitor deforestation and conduct surveillance missions against illegal invasions and activity on their land (Box 3.4).

Box 3.4. UAS Pilots for Forest Monitoring/Restoration in Panama and Brazil

Case 1: Mangrove restoration in Panama

In 2021, Panama Flying Labs partnered with the WeRobotics engineering team and Beta Earth to conduct drone test flights for an aerial seeding and mangrove restoration pilot in Oeste and Coclé, located in the Central Province of Panama.

The drone-optimized release system developed for the pilot by the WeRobotics engineering team could carry 750+ seed balls per load distributing them accurately over one hectare in less than five minutes. For mangroves, 120 propagules were dispersed near coastal regions at an altitude of 2-3 meters from the fully autonomous system. It demonstrated promising results, with a good percentage of them successfully penetrating and entering the soil.

The high efficiency of drone technology was evident during a total of 20 flights over three days. Approximately 4.1 hectares were covered via drone flights, dispersing 5,000 seed balls and 120 mangrove propagules. Before the trial, the reforestation method in the two communities relied on hand planting, which was tedious, time-consuming, and challenging, in muddy terrain and difficult-to-reach areas. Furthermore, Panama Flying Labs led several community engagement activities to ensure the long-term protection of the newly planted areas.

Another mangrove related project was conducted by Panama Flying Labs in the same year. Drones were used to monitor both sea level rise and the mangroves of the uninhabited North and South Zapatilla Islands. Collected imagery data outlined the boundaries of the mangrove forests and helped create orthomosaics, digital terrain models, and digital surface models. They were published in the Monitoring Protocol for the Panamanian Mangrove Ecosystem and shared with local institutions and organizations for strategic planning and conservation efforts. Demonstrating great efficiency, more than 89 hectares of total area were mapped for both islands using only six drone flights (Flying Labs and WeRobotics, 2023).

Box 3.4. UAS Pilots for Forest Monitoring (cont.)

Case 2: Stronger monitoring, protection, and land rights for indigenous people of the Amazon in Brazil

Indigenous territories serve as key deterrents against the advance of deforestation; however, monitoring and protecting the vast areas, and their wildlife, with limited resources poses significant challenges in many tropical forest-rich countries.

To address this obstacle and protect Indigenous territories, a partnership was established between the Kanindé Ethno-environmental Defense Association, WWF-Brazil, and the Uru-Eu-Wau-Wau Indigenous people. Since 2019, the partnership's activities have focused on training Indigenous community monitors to use technologies such as drones, remote sensing, and mobile phone applications to surveil and monitor their territories in the State of Rondônia in the Brazilian Amazon (WWF, 2022).

In March 2021, Kanindé and WWF-Brazil, together with Solved Soluções em Geoinformação Ltda, expanded the work by building the Kanindé Deforestation Monitoring System (SMDK), an early warning satellite alert system used to track and report illegal activities. The SMDK covers 22 indigenous territories, with a buffer of 10 kilometers around each territory, totaling 6.4 million hectares.

Drones have been used since 2019 and the SMDK began its operation in August 2021. Up to April 2023, reports for over 1,350 validated alerts were generated. Paired with the use of drones and mobile applications, the SMDK supported the seizure of more than eight trucks with illegally extracted wood from the Uru-Eu-Wau-Wau Indigenous Land, motorcycles, chainsaws, and heavy machinery used by illegal loggers. This illustrates that integrated participatory monitoring using technology can be successful.

Additionally, drones can aid in the fight against forest fires when used by indigenous volunteer fire brigades for integrated fire management activities and forest fire combat (WWF, 2023).

Building on this successful experience, the project expanded into new areas by actively training and equipping other indigenous communities across Rondônia, Acre, Pará, Mato Grosso, and even reaching groups in Peru, Colombia, and Ecuador. Almost 300 community monitors have been trained and 50 drones have been donated (Spina Avino, 2024).

In comparison to traditional fieldwork, the low cost and time economy of using drones for tasks like monitoring territories or mapping forest inventory can enhance the detail and efficiency of data gathering. Therefore, drones should be promoted and eventually become standard tools to help assess progress and contribute to the adaptive management, conservation, and monitoring of protected and community areas.

3.5. Disaster Risk Management

3.5.1. How UAS Can Address the Challenges

After Asia and the Pacific, the LAC region is the most disaster-prone region in the world and climate change will only exacerbate regional conditions (OCHA and UNDRR, 2023). LAC is a region highly exposed to extreme weather events and natural disasters such as earthquakes, hurricanes, floods, tsunamis, and droughts. The World Risk Index (2020) shows that over 50 percent of LAC countries are ranked high or very high for natural disaster occurrence and are currently presenting high or very high levels of vulnerability to these hazards—including susceptibility, adaptability, and ability to cope with these events (Bündnis Entwicklung Hilft and Ruhr University Bochum, 2020). Each event has a huge impact on lives and society: not only do they create a humanitarian crisis, but they wreak havoc on infrastructure, and can reduce physical and digital connectivity leaving some remote or rural communities completely cut off from vital services. All this has an exacerbating effect on development challenges like poverty, undernutrition, poor access to healthcare, isolation of remote areas, and limited access and affordability to main goods and services. According to the World Bank, natural disasters in Latin America and the Caribbean push between 150,000 and 2.1 million people into extreme poverty every year (World Bank, 2021). Earthquakes, floods, and storms are the natural events associated with the highest levels of death, impacted populations, and economic losses (OCHA, 2020) and in 2000–19 alone, 152 million people in the region were affected by 1,205 disasters.

In the face of this growing pressure, countries urgently need to prepare, adapt, and respond to disasters that are likely to become more frequent and potentially more severe (World Meteorological Organization, 2023; UNFCCC, 2022; OECD, 2023b). Investing in new technologies, products, and natural assets to support efforts to reduce vulnerabilities, improve preparedness and mitigation efforts, and increase the speed of response could reduce the impacts of climate change in a meaningful way while building resilient societies and infrastructure in the region (OECD, 2023b).

To enhance the efficiency of disaster management, it is crucial to embrace new methodologies and cutting-edge technologies that complement traditional approaches. Establishing a robust system involves incorporating telecommunication capabilities and remote sensing, as well as developing databases geared toward spatial and temporal data storage to effectively managing the vast volume of information. In this regard, UAS can be a great asset to support the entire disaster management cycle.

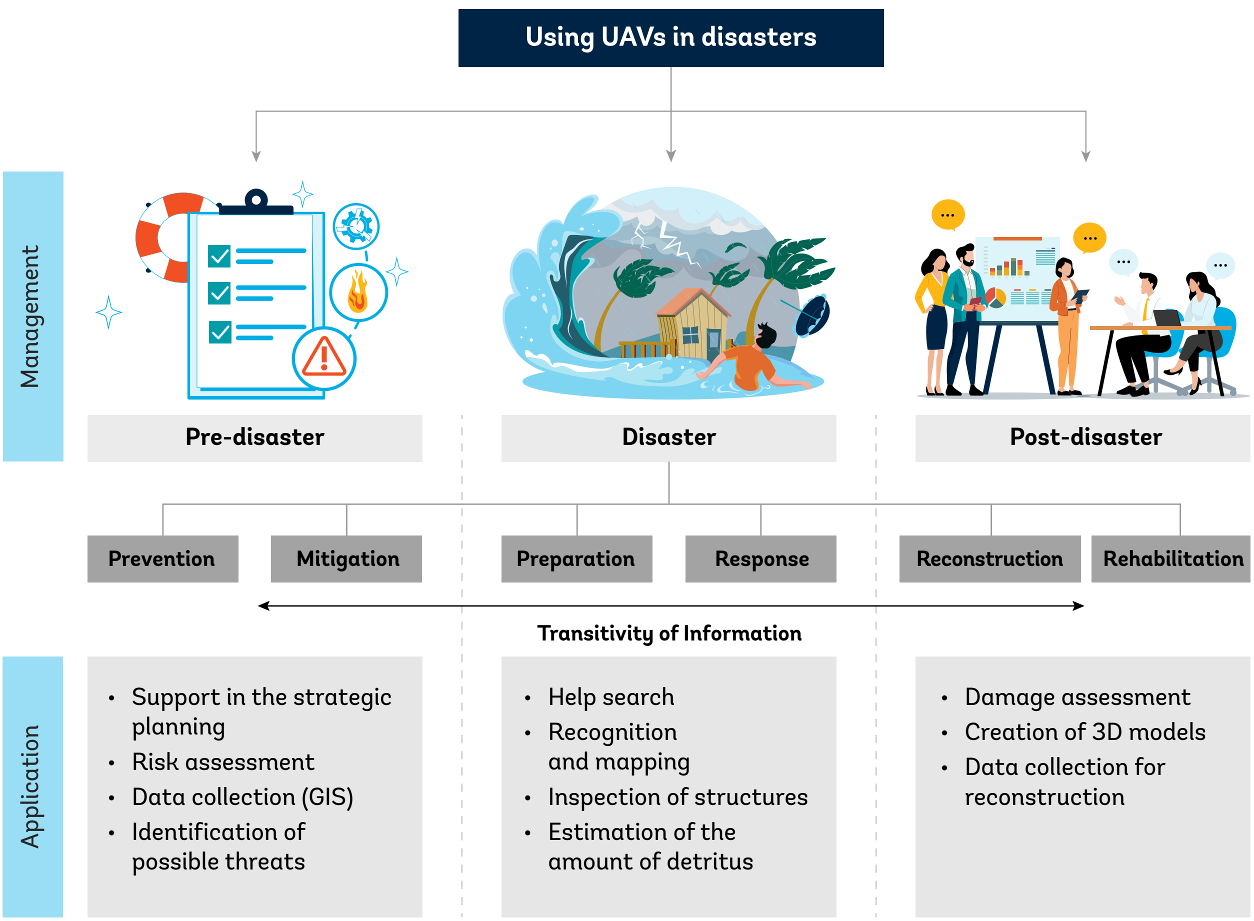
UAS are gaining ground as a new technology in risk and disaster risk management, as a tool that contributes to prevention and response before, during, and after disasters. Because of the wide range of applications covered by the technology, drones offer effective solutions for supporting disaster risk management (DRM) at every stage. As summarized in figure 3.1, DRM can be categorized in three main phases: before, during, and after disaster (World Bank, 2019). There are numerous UAS applications for each of these phases. Here are a few examples:

- **Pre-disaster phase, mitigation and prevention:** Use cases include mitigation related vulnerability assessments and risk modelling. Drones can map and monitor the topography and surface features of areas susceptible to and impacted by fires, storms, landslides, earthquakes, or floods. High-resolution drone imagery enables the creation of orthophotos and 3D models that are used for risk modeling of disasters, supporting the identification of vulnerable points to be addressed with preventive measures.

- **During disaster phase, preparation and response:** The combination of drones and satellite technology—especially during cloud cover—can support rapid response providing data collection and analysis in an effective and timely manner. In the event of floods and earthquakes, drones equipped with thermal imaging cameras, noise sensors, binary sensors, and vibration sensors can effectively identify individuals in need of assistance or evacuation, determining optimal evacuation routes in real time. Not only does this approach mitigate the risk to additional lives, but drone equipment is also often more agile than human responders, enabling access to hard-to-reach areas and conducting efficient sweeps and at lower operational cost.

- **Post-disaster phase, reconstruction, and rehabilitation:** High-resolution aerial images captured by UAS play a crucial role in accurate damage assessments, reconstruction planning, and mapping of affected areas. These images provide valuable insights that inform reconstruction projects and account for any alterations to the land caused by the disaster. They support the integration of new elements into settlement planning, utilities, and resilience components, thereby reducing the potential vulnerability of affected communities to future events.

Figure 3.1. Relevant Uses of UAS in Disasters



Source: World Bank (2019) adapted from Ludwig et al. (2016).

The adoption of UAS technologies for DRM has gained momentum in LAC due to the frequent occurrence of natural disasters. The pivotal role of disaster management was underscored in 2012, when drones were first used in Haiti for post-earthquake damage assessments. Subsequently, numerous countries in the region, including the Dominican Republic, Ecuador, Chile, Brazil, and Colombia, have integrated this technology into risk management and mitigation, as well as into disaster response and recovery efforts. Various regional and international organizations, and entities like DroneDeploy, play a crucial role in educating and training public safety personnel on the use of unmanned aviation technology and related systems for emergency operations.

3.5.2. Most Common Business Models

Different business models for drone use in DRM proved to be relevant, involving public agencies, private sector, NGOs, and civil society. An important element in ensuring the effectiveness of the response is to prepare the capacity of the various players for a coordinated response. Exercises such as simulacrums can be used to test this ability.

First responders, typically government agencies, can build internal drone capabilities by training in-house operators in hardware and software deployment for emergencies. This is often funded by the government, NGOs, development partners, and private companies.

In emergency situations, volunteers with drone skills can make an effective contribution. To maximize value of UAS and integrate them safely into other activities, standard operating procedures and training programs need to be put in place beforehand. In fact, it is recommended that UAS regulatory frameworks include definitions and procedures for emergency operation to have a clear, expedited, and functional response. Funding for these programs can come from development institutions, NGOs, donors, sponsors and in collaboration with the relevant government authorities.

As the cost of drone services can be a barrier, some private companies may offer free drone services as part of their corporate social responsibility. This contributes to faster and more cost-effective disaster management than traditional methods.

Box 3.5. UAS as a Critical Tool for Disaster Response in Dominica

On September 18, 2017, Category 5 Hurricane Maria made landfall on Dominica, resulting in widespread damage and loss of life. The hurricane's strong winds, heavy rainfall, and high vegetation load from the slopes, along with the transportation of soil and boulders by water, led to numerous multi-hazard situations. Approximately 10,000 landslides were recorded due to the extreme rainfall and uprooting of trees. The hurricane caused 64 deaths, affected 71,393 people, and resulted in total damages estimated at US$1.456 billion (Schaefer et al., 2020).

Following this devastating event, drones were deployed to assist the local community and to aid in the creation of photogrammetric maps of the island to support government recovery efforts. Drone pilots from the University of Maryland UAS Test Site partnered with the Canadian relief organization Global Medic for this critical mission. Despite facing operational challenges and with 90 percent of the power grid remaining offline, volunteers efficiently pre-identified 59 affected locations and meticulously mapped over 5,700 acres in a two-week period.

The acquired drone data underwent sophisticated analysis using machine learning models tailored for damage assessment. This innovative approach, overseen by a single individual and completed in a mere 30 minutes (AOPA, 2018), facilitated the rapid detection of 106 damaged rooftops.

Similarly, in 2020, a study dedicated to the use of drones as a cost-effective and rapid means for accurately quantifying post-hurricane changes in Dominica was published (Schaefer et al., 2020). As part of the research, the UAS survey showcased many useful findings regarding varying degrees of damage relative to the passage of Hurricane Maria: zones of storm surge run-up, coastal erosion, and debris deposition; areas of river erosion, landslides, and landslide-dams; locations of sediment deposition, boulder trains, and tree debris. The survey also facilitated a systematic analysis of the geomorphological settings of collapsed bridges, as well as the few bridges that survived the floods and debris flows revealing valuable "build back better" features.

The UAS survey was relatively rapid and cost-effective, with 44 sites surveyed in two weeks by two drones, each manned by two staff members (the pilot and observer). Other survey methods, such as airplane survey and photogrammetry, aircraft LiDAR and processing, sub-meter satellite and total station surveying, were considered. However, they proved relatively expensive, less detailed with cloud-cover limitations, and could not be organized in the short time frame of this project (Schaefer et al., 2020).

The results demonstrate that low-cost UAV surveys can be a rapid, relatively accurate, and cost-effective tool for disaster management applications, particularly damage assessments. UAVs are accessible technology that require a low investment in equipment and training, potentially bringing dividends in improved disaster preparedness, response, and recovery. As a result, according to the study, it is recommended for countries at high risk of natural disasters to develop an "in-country" capacity for low-cost UAV surveys, building teams that can create pre-disaster baseline surveys, respond within a few hours of a local disaster event, and provide aerial photography useful for damage assessments carried out by local and incoming disaster response teams (Schaefer et al., 2020).

4

Drone Regulation in LAC

Explore the critical role of tailored regulatory frameworks in overcoming barriers to drone development in the region. This involves navigating the balance between safety and innovation, guiding the integration of UAS into the airspace to meet industry needs and public safety. Establishing comprehensive regulations is a key milestone to unlock the transformative potential of drones in various sectors.

A lack of regulations adapted to each country's needs appears to be one of the main barriers to the development of unmanned aircraft systems (UAS) ecosystems in LAC. Like any disruptive innovation, UAS pose several challenges in terms of how they are developed and used and how they are integrated safely into the airspace. Faced with this novelty, the role of the public sector, generally embodied by the Civil Aviation Authority (CAA), is to provide a framework for new uses in the public space and to guide the introduction of the innovation in a coordinated and coherent way that serves all the key stakeholders that form the UAS ecosystem. In this sense, the regulatory framework plays a fundamental role. As they strive to stimulate growth and innovation across sectors, regulators must not only uphold safety concerns for citizens, but they must also meet the needs and expectations of the industry. Therefore, establishing comprehensive regulations is a key milestone for unlocking the potential of drones for developmental uses. (For more details on the characteristics of drone regulations and their role in fostering the ecosystems, please refer to Appendix 3.)

4.1. Status of Regional Regulations

An overview of UAS regulation in LAC shows that most countries have already begun to adopt some form of regulation, but the situation remains highly heterogeneous. Seven fundamental parameters can serve as a guide for assessing drone regulations to ensure operational safety, legal certainty, and industry growth. These include:

i. Ensuring regulations are comprehensive and adaptable to a variety of drone operations

ii. Establishing performance-based standards to facilitate technological progress

iii. Adopting an operations-centric, risk-based approach

iv. Addressing safety, security, privacy, and environmental concerns

v. Designing regulations to be as simple as possible

vi. Requiring resources that are proportionate to the safety benefits and implementation costs

vii. Creating regulations through a process that is open and transparent.

These guidelines help create a favorable environment for the safe and sustainable operation of UAS, while also fostering industry development.

The evaluation of each country's regulatory framework through descriptive analysis involves a comprehensive scoring system and a statistical overview that pays particular attention to key aspects like official drone regulation, unmanned traffic management (UTM), drone registration, and insurance requirements. Through this meticulous research, countries were categorized into stages: no regulations, early stage, intermediate, and advanced. This categorization is based on a weighted scoring system that reflects the completeness and sophistication of their regulations, the capacity for UTM, and the establishment of necessary legal structures for drone operation, registration, and insurance. These stages provide a clear benchmark of each country's regulatory environment and its alignment with the seven fundamental parameters for safe, sustainable, and legally certain UAS operations.

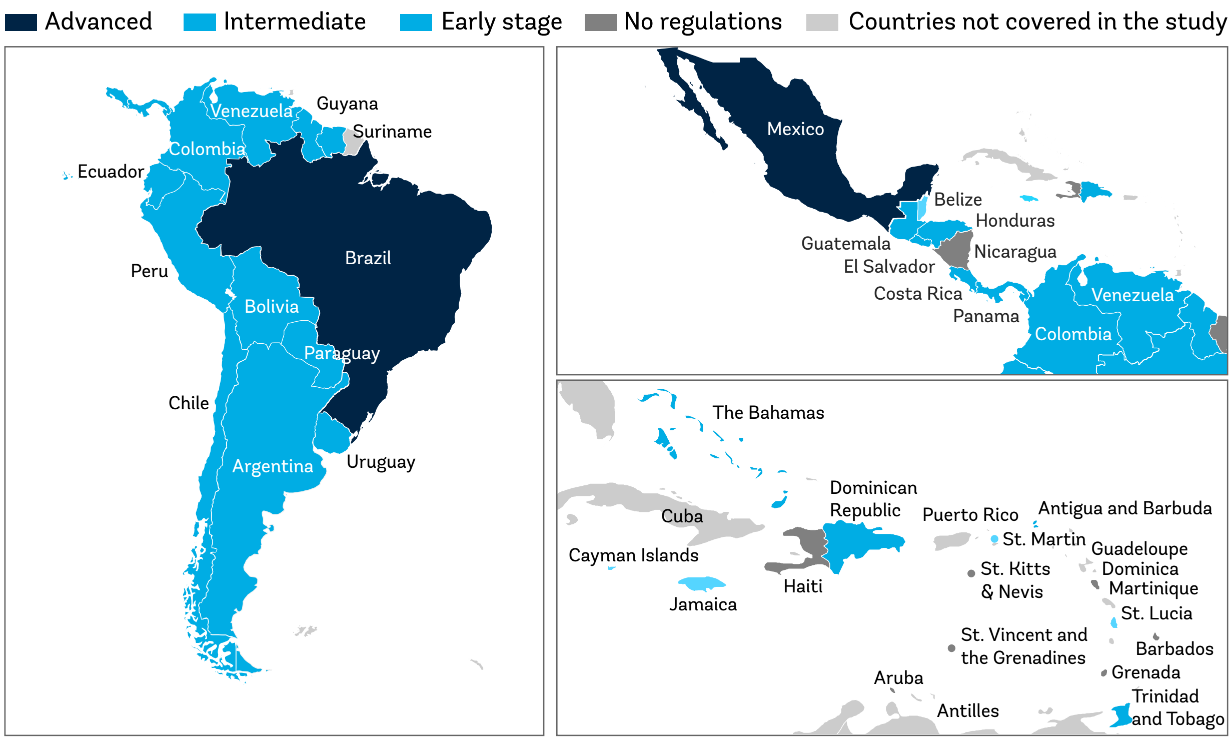
To gain a better understanding of the state of regulation in LAC, the World Bank conducted interviews, studies, and surveys of the various initiatives underway in the region as part of the regional work previously mentioned. The results are depicted in Figures 4.1 and 4.2. From the 35 analyzed countries:

- Two countries, Brazil and Mexico, managed to establish advanced official drone regulations that envision advanced use cases, suggesting BVLOS operations in which the pilot has no direct visual contact with the drone and performs the mission without direct observer assistance.
- Twenty-five countries demonstrated regulations at an intermediate or early stage of development. This designation means that official regulations were established recently or are not as comprehensive and up to date as advanced regulations.
- Eight countries, mostly small island countries in the Caribbean, do not have official regulation.

While most countries have begun to develop their regulations, most are not yet optimal for the implementation and use of advanced drone applications at scale. If Brazil and Mexico have developed relatively advanced regulation compared to the rest of the region, the countries considered in the early or intermediate stages are still in the process of implementing comprehensive regulations or updating their drone regulations to match the pace of technology development and market needs.

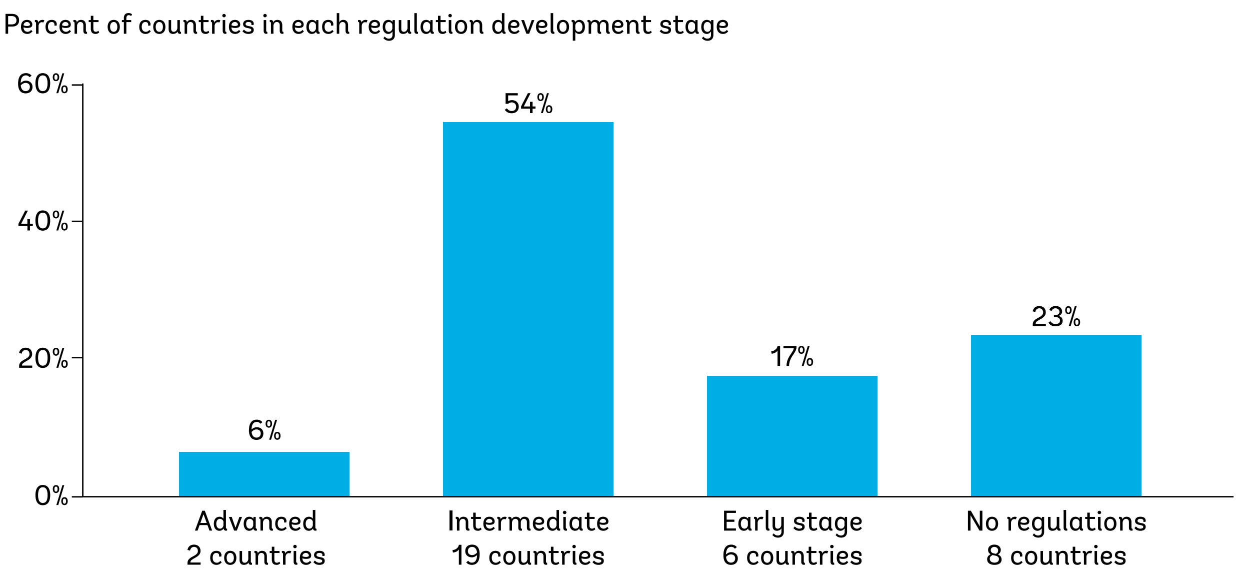
Each country utilizes its own national civil aviation authority, which is responsible for local airspace related legislation as required internationally and overseen by the International Civil Aviation Organization (ICAO). In some cases, they follow ICAO recommendations, while others look to the example of more advanced regulations from established drone ecosystems. Entities do not follow a unified framework across the region. Typically, the current LAC regulations follow global trends at different scales. While using existing frameworks for a first draft of regulations may seem relevant, it seems important to continue the efforts of regulators to develop rules that are fully adapted to the context and strategic development goals of the UAS ecosystem for each country.

Figure 4.1. Stages of Drone Regulation Development in the LAC Region



Source: PwC 2021a.

Figure 4.2. Current State of Regulations in LAC



Source: PwC 2021a.

Although more than 75 percent of countries in LAC have some form of specific drone regulations in place, there are questions about how conducive these are to boosting UAS adoption in the region (PwC, 2021b). In many cases, there is a mismatch between the existing regulatory framework, the actors, the ability to comply with regulations, and the needs of the country and the ecosystem. These challenges, along with the limited capacity of regulators to embrace and adapt to the rapidly changing characteristics of UAS, appear to be some of the main barriers to the development of strong UAS ecosystems in Latin America and the Caribbean.

4.2. Recommendations for Developing UAS Regulations in LAC

Strengthening, adapting, and establishing regulations for LAC will be among the major steps in supporting the development of UAS in the region. These recommendations are drawn from concrete experiences where the Bank has been involved.

- **Regulations should be adapted to the context of each country.** The LAC region is characterized by a wide range of situations in terms of development challenges and maturity of the technology and its ecosystem. While most countries share similar challenges–vulnerability to climate-related disasters, poverty, inequalities between rural and urban areas, lack of accessibility, and insufficient infrastructure–the magnitude and precise nature of the challenge can vary considerably. Economies vary in size, from highly advanced countries like Brazil and Mexico, to small island nations in the Caribbean. Institutional capacities are also wide ranging. Similarly, the adoption of UAS is at very different stages. Consequently, it is advisable that drone regulations are tailored to the specific needs and circumstances of each. It is important to draft and update regulations with a needs analysis to identify the development stage of the drone ecosystem, the applications that should be developed first, the stage of the market, and which development objectives are sought. Such work calls for a participatory process involving various sector stakeholders.

- **A progressive approach to regulation can be beneficial for the development of technology.** In the process of formulating regulations, it is crucial to decide whether the principal objective is to accommodate small-scale UAV flights on a case-by-case basis or to facilitate routine at-scale UAV operations. This ultimately dictates the level of regulatory advancement required. Various levels of regulatory advancement enable distinct drone operations. While less developed frameworks do not impede advanced operations, more robust regulations enhance safety and enable the execution of large-scale operations (Figure 4.3). Nevertheless, the adoption of an incremental approach to developing a regulatory framework proves to be the most beneficial solution for both authorities and the drone industry. This approach encourages the industry to mature, and allows authorities to build capacity gradually, in a stable and understandable regulatory environment that is based on the country and its institutional reality. To enable the initial integration of UAS into the airspace, principal flight requirements based on factors such as aircraft weight, operation location, and complexity could be defined. This would at first restrict permissible operations to lower-risk flights, while still allowing flexibility to accommodate future technologies and applications. For example, initially focusing on visual line of sight (VLOS) operations that encompass the majority of UAV operations. As the industry matures, additional requirements such as pilot licensing, aircraft registration or airworthiness certification can be introduced to allow for higher-risk, at-scale operations.

Figure 4.3. Main Characteristics of Various Regulatory Development Levels

Level 1 | Basic

- Low risk drone operations
- Open/basic category of drone operations foresees technical and operational restrictions to perform flights
- Low level of the authority involvement
- Requirements of operator and pilot responsibilities
- VLOS operations in the form of leisure activities with limited number of commercial ones permitted

Level 2 | Intermediate

- Medium risk drone operations
- In addition to operations in open/basic category, drone operations in specific category are allowed
- Very few operational limitations, BVLOS operations are foreseen with the operational autorisation/ submission form approved by the authority/predefined risk assessment
- Drone operations such as cargo delivery, agriculture, surveillance and inspection missions are allowed

Level 3 | Advanced

- High risk drone operations
- In addition to operations in open/basic category and specific category, drone operations in certified category are allowed
- Certified drone, operator certificate and pilot license are required
- Establishment of the Unmanned Aircraft System Traffic Management (UTM) and its services
- Cargo operations and dangerous goods delivery (e.g. blood samples over heavily populated areas)

Level 4 | Highly-Advanced

- High risk drone operations on a larger scale
- In addition to all the categories of drone operations, UTM and Air Traffic Management (ATM) systems integration is foreseen
- The range of UTM services is wider
- Drone operations in the form of urban deliveries and transportation of people

Source: PwC 2021a.

- **The right balance of regulation style is essential to enable safe operation of UAS, and legal certainty while encouraging initiatives for their development.** Drone regulations play a pivotal role in fostering the growth of the UAS ecosystem. It is, however, crucial to ensure they are balanced and effective. Overly restrictive or disconnected regulations can inadvertently hinder the development of the evolving industry. Adaptability is vital for the industry and for the dynamic nature of the drone ecosystem. Embracing this dynamism in the regulatory framework can help ensure that the system thrives and adapts along with the latest industry development and use cases. To achieve this balance, it is important to rely on sound risk analysis for each country and use case. Through risk analysis, the riskiest operations that require specific assessment for the operation will be identified and the more common, less risky operations, will be granted more flexibility and less involvement by regulation. In addition, the dynamic aspect of these uses needs to be considered. To stay abreast of the ever-changing industry, risk analyses need to be regularly updated and adapted to changes in the regulatory framework. To identify the changes needed, the regulator must monitor the practical applications based on feedback from various operators.

- **The definition of a regulation should be accompanied by the resource and means planning associated with its application.** The process of making regulations operational requires a series of concrete, resource-intensive tools, and procedures. It also requires continuous monitoring to guarantee their adaptability given the evolving nature of UAS applications. In addition to the general rights and protections that should be established for UAS users, the resources informing them of the obligations connected to regulations should also be mapped out. This requires institutional structures, including qualified human resources that are dedicated to monitoring, support, and communication. It is important that the LAC countries take this aspect into account to propose regulations that are both applicable in practice and commensurate with their resources.

- **A certain level of harmonization and alignment of regulations within the UAS ecosystem and industry could be beneficial, enabling stronger cross-border collaboration.** Countries in the LAC region have been developing and updating their drone regulations over the years. However, these efforts have primarily been individual endeavors based on international benchmarks from the Federal Aviation Administration (FAA), European Union Aviation Safety Organization (EASA), or ICAO models, rather than as the result of a collaborative regional approach to develop coordinated regulations. This approach has indirectly fostered a sense of consistency and adherence to the best practices across those countries. On a regional or sub-regional scale, it would be interesting in the medium term to promote a participatory process to regulation development. This would allow interoperability between UAS at the regional level while fostering synergy and cooperation between LAC countries.

Box 4.1. Developing UAS Regulation in Haiti

Through technical assistance under the Caribbean Regional Air Transport Connectivity Project-Haiti,[11] the World Bank has been supporting the Government of Haiti as it drafts the first regulation for the use of unmanned aircraft systems (UAS). Under the leadership of the country's civil aviation agency, the Office National de l'Aviation Civil (OFNAC), and with the support of PwC, a methodology for structuring the future UAS regulation has been developed. This method is based on three steps, illustrated in Figure B4.1.1.

Step 1: Assess Needs of the local context. The aim of this methodology is to produce a regulation tailored to the specific context and challenges of this country, which presents the highest poverty rate in LAC (OPHI and UNDP, 2022). The poor state of infrastructure, the lack of accessibility in rural areas, and the high level of exposure to natural hazards (disasters, hurricanes, floods) make UAS applications particularly interesting as a means of supporting development initiatives or emergency aid. In addition, it was important to consider the particularly high security threats amid high levels of political instability. For this reason, the first step was to identify the application needs of UAS in the country. This was done through participatory workshops involving the public sector stakeholders that are potential users of UAS applications.

Step 2: Draw lessons from other countries. In addition to the problems specific to Haiti, it was also important to seize the opportunity to build regulations on the lessons learned from other countries where regulation has been developed. For that, a benchmark of four existing frameworks was carried out: the regulations of Rwanda, the Federal Aviation Administration of the United States (FAA), the European Union Aviation Safety Agency (EASA), and the drone model regulation of the International Civil Aviation Organization (ICAO). Those frameworks, with different levels of advancements, were selected for their detailed characteristics so that best practices could be extracted and integrated into a regulatory framework for Haiti in service of the country's needs and requirements.

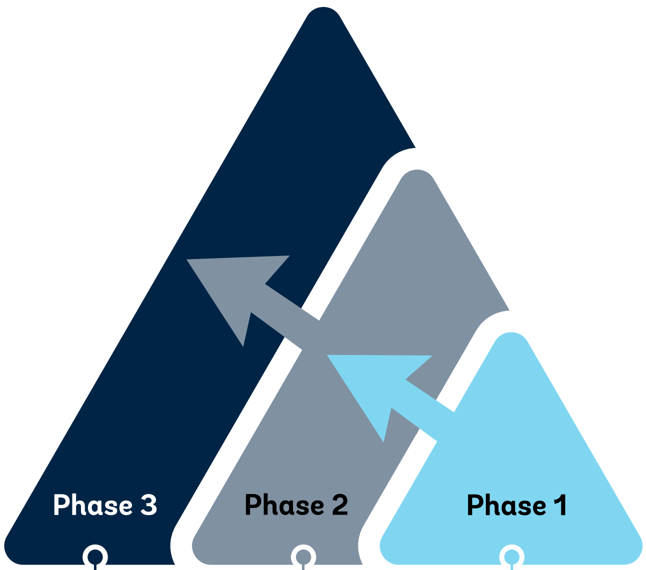
Step 3: Define the critical elements of the regulation. In the third stage, based on the elements gathered earlier, the plan for future regulation is drafted in a consultative and iterative way, defining its various components. This includes identifying the means of support to be developed to make the various components of the regulation applicable in practice. This work is carried out in consultation with stakeholders.

It is important to note the participatory nature of the approach, which has enabled bottom-up feedback from the various stakeholders, to guarantee the relevance and usefulness of future regulation. This work has laid a solid foundation for the next steps to come—drafting the detailed content of the regulation, followed by its implementation.

[11] The technical assistance was approved on 2022-06-27 and is expected to conclude in April 2023. It has been financed by a grant of the PPPAF (The Public-Private Infrastructure Advisory Facility)

Box 4.1. Developing UAS Regulation in Haiti (cont.)

Figure B4.1.1. Methodology for Building Haiti's Regulatory Framework



Define the critical elements for a UAS regulation in Haiti

The key elements, components and a proposed table of content were drafted to showcase the main recommendations that could be included for the development of UAS regulations for the country. Workshops and consultative meetings with key players and stakeholder were held to present, test and validate the identified regulatory components and elements.

Draw lessons learned from other countries

4 regulatory benchmarks: Rwanda (RCAA), USA (FAA), ICAO, EU (EASA) were selected to conduct a detailed analysis and cover varied implementation, advancement and purpose levels of regulations in order to have a comprehensive understanding of different frameworks, extract lessons learned that could be relevant for its potential applicability in Haiti.

Need assessment of the local context

An assessment of the current state of drone regulations and the Haiti's requirements was needed to gain a better understanding of the primary needs and to develop the most suitable recommendations for identifying the key requirements for a regulatory framework in the country.

Source: PwC 2021a.

5

An Emerging Market with a Potential for Job Creation

Examine the growth prospects of the drone industry through a detailed modeling of 35 countries. It projects the market's theoretical maximum size by 2026, considering various development scenarios and local use cases. The industry's speed and scale will hinge on effective facilitation measures and the fostering of robust UAS ecosystems.

The nascent unmanned aircraft systems (UAS) industry is set to grow, but the speed and scale of its development will depend on the facilitation measures in place. With the aim of gauging growth prospects, the World Bank study included detailed modeling (by PwC) of the drone market potential in LAC.[12] Conducted in 2021, the assessment was based on an in-depth analysis of 35 countries. It used historical data to project the theoretical maximum size of the market, defined as its potential up to 2026, simulating the potential values according to the conditions used. The projection considered various development scenarios to evaluate the impact of fostering UAS ecosystems (Figure 5.1). Using both bottom-up and top-down estimation approaches, the methodology defined the market potential and the current market size in consideration of factors like technology adoption rates, current initiatives, and international benchmarks. Additionally, the analysis included 30 broadly adopted UAS use cases tailored to each country's local market.

Figure 5.1. Drone Ecosystem Development Scenarios for the LAC Region

Scenario	Key assumptions
2021 baseline	• 2021 baseline is an estimation of the current shape of the drone ecosystem in the region • It is presented illustratively to serve as a baseline and allow for comparison with future forecasted market values
Basic scenario	• If no specific actions are undertaken, but also no initiatives to hinder development of the drone ecosystem are introduced, the market is forecasted to grow slowly, as indicated by the basic scenario • It will be driven by developments on the international drone market and growth of drone technology adoption in various industries
Target scenario	• Target scenario assumes that countries will introduce the proposed initiatives regarding various parts of the ecosystem • It will allow the market to develop quickly and efficiently, similarly, to pace with which analysed benchmarks developed
Optimistic scenario	• Optimistic scenario shows how the market may potentially look like if development of the drone ecosystem and introduction of incentives allowing its growth to become a priority of local public policy efforts • With systemic support to innovation and technological transformation, the local drone markets are forecasted to quickly catch up to international leaders in the fields
Full potential scenario	• Full potential scenario is presented illustratively to show the hidden potential and impact the UAS technology may have on the economy in the long run • It assumes that all use cases that are technologically feasible, are performed by drones, and all other ways of providing similar services (e.g. manual monitoring of construction progress or manual crops monitoring) are replaced by drones

Source: PwC 2021b.

[12] Market potential describes a value of the market given all potential applications of UAS are realized and traditional methods replaced by UAS services. Market potential for UAS services in the LAC region is forecasted to reach $4.7 billion in 2026, growing at CAGR (2021–26) of 10 percent.

Spanning a five-year horizon, this modeling revealed that if governments implement supportive actions to enable drone usage in their countries, the potential market growth is substantial. As illustrated in Figure 5.2, in a scenario that assumes that governments will introduce a series of ecosystem development initiatives (Figure 5.3), the forecast is that market volume could increase fivefold over a five-year period. These estimates underscore the need to secure governmental support and capitalize on the potential of the drone sector in the upcoming years.

Figure 5.2. Drone Ecosystem Development Initiatives, 2021–26

Drone Ecosystem Framework

Drone Ecosystem Development Initiatives

Regulations and Processes	Digitalisation and Automation	Awareness and Promotion	Knowledge and Education	Demand and Entrepreneurship
Clear regulatory framework to ensure safety while stimulating innovation and enabling future use cases	Digitalisation of processes to facilitate ease of providing services for SMEs and scaling capacity of public institutions	Building trust and awareness among public stakeholders, society and industry to facilitate the adoption of innovative and relevant UAS solutions	Growing human capital by providing access to high quality education to stimulate scaling and rendering of innovation	Stimulating innovation by providing entrepreneurs with the means to accelerate their market entry and scaling the development of the technology
Transparent processes and procedures to facilitate straightforward compliance with regulations and related processes	Introduction of digital unmanned traffic management services to control and safely integrate UAS into the airspace	Fostering innovation by connecting startups, industry and research	Facilitating sustainable airspace safety by educating users and stakeholders about regulations, best practices and responsible behaviours	Stimulating demand for drone products and services by providing instruments to activate the market

Source: PwC 2023.

The expansion of the drone sector is poised to create hundreds of new jobs in areas like services, hardware and software development, research and development (R&D), training, education, and more. The aim of the analysis was to assess the job creation potential of the drone service market in LAC. In an assumed target scenario, it is estimated that approximately 195,000 jobs could be generated in the region in 2021–26. These new roles will cover a diverse range of functions. The largest segment is expected to be technical positions that includes data processing and analysis, data scientists, engineers, drone operators, and management roles. Additionally, the rise in commercial UAS services is likely to create more jobs, especially for employees in major companies who leverage drone-captured data for strategic decisions and for support staff in sales, marketing, finance, human resources, and procurement. The sector is also anticipated to offer work opportunities across drone-related services such as drone instructors, regulatory experts working for the government, a salesforce for drone hardware, and much more. Although the drone service industry is expected to create employment opportunities across the LAC region, the impact and number of jobs created is expected to be greater in countries with intermediate to more developed levels of UAS adoption.

Figure 5.3. Drone Ecosystem Development Potential, 2021–26

	2021 baseline	Basic scenario	Target scenario	Optimistic scenario	Full potential
Market potential	USD 4.7 Bn				
Market value	USD 168.6 Mn	USD 425.2 Mn	USD 850.5 Mn	USD 1 700 Mn	USD 4.7 Bn
Jobs creation	46 318	108 244	195 061	371 547	1 051 028
Number of commercial UAS	56 176	182 062	332 300	643 625	2 137 893
Number of recreational UAS	222 390	681 347	1 179 743	2 268 754	7 671 651

Comments

- 2021 baseline is an estimation of a current shape of the drone ecosystem in the region
- If no specific actions are undertaken, but also no initiatives to hinder development of the drone ecosystem are introduced, the market is forecasted to grow slowly, as indicated by the basic scenario
- Target scenario assumes that countries will introduce the proposed initiatives regarding various parts of the ecosystem
- Optimistic scenario shows how the market may potentially look like if development of the drone ecosystem and introduction of incentives allowing its growth to become a priority of local public policy efforts
- Full potential scenario is presented illustratively to show the hidden potential and impact that UAS technology may have on the economy in the long run

Source: PwC 2023.

In addition to the anticipated growth, current and emerging approaches for integrating UAS technology into social and environmental applications at the community level (see Box 5.1) are expected to continue to emerge. This trend will lead to new opportunities for local communities and result in a need for training and education in drone use, data management and digitization, and a need for data processing and analysis capability at the entry level.

Box 5.1. The Rise of Community Drones in the LAC Region

The emergence of community drones in recent years has presented a transformative approach to addressing the environmental and social challenges encountered by local communities globally. Community drones involve the use of unmanned aircraft systems (UAS) by indigenous and local communities, marginalized residents, and community groups in urban or peri-urban areas. This use primarily aims to address specific needs and interests, involving varying degrees of community participation throughout different stages including project planning, data collection, analysis, and utilization of the generated information (Vargas-Ramírez and Paneque-Gálvez, 2019; Sauls et al., 2023). Limited research on community drones worldwide suggests that a significant portion of community drone initiatives are concentrated in developing countries with Latin America emerging as a leading region (Vargas-Ramírez and Paneque-Gálvez, 2019; Sánchez-Zuluaga et al., 2023; Sauls et al., 2023).

This phenomenon can be attributed to several factors, notably the prominence of community organizations and a participatory culture in LAC. These elements have fostered the community drone initiatives, which offer innovative solutions for environmental monitoring and disaster response (Vargas-Ramírez and Paneque-Gálvez, 2019; Paneque-Gálvez et al., 2014, 2017). Furthermore, in recent decades, many indigenous groups in LAC have gained official recognition of customary lands, necessitating monitoring and protection against various threats (Vargas-Ramírez and Paneque-Gálvez, 2019; Sauls et al., 2023; Spina Avino et al., 2022). The increasing prevalence of extractive activities has spurred the emergence of environmental justice movements, with communities using drones to monitor environmental impacts and defend their territories (Vargas-Ramírez and Paneque-Gálvez, 2019). Active social movement groups in urban and peri-urban areas have been employing community drones for various purposes, such as monitoring threats like landslides, in participatory mapping, and for disaster preparedness activities (Paneque-Gálvez et al., 2017; Vargas-Ramírez and Paneque-Gálvez, 2019).

Box 5.1. The Rise of Community Drones in the LAC Region (cont.)

Community drones play a crucial role in boosting a local community's capacity for territorial monitoring and management. High-resolution aerial imagery and data acquired by drones empower communities to claim land and territorial rights, defend traditional land-use practices, and monitor environmental threats such as forest fires, illegal deforestation, unregulated urbanization, and reforestation efforts. Various indigenous communities in the Amazon basin have successfully monitored and defend their territories (Paneque-Gálvez et al., 2017; Vargas-Ramírez and Paneque-Gálvez, 2019; Sauls et al., 2023; Spina Avino et al., 2022, 2023). Moreover, due to the topography of LAC, aid organizations often face challenges reaching remote populations. Community drones have proven instrumental in strengthening disaster resilience by facilitating damage assessments following natural disasters, supporting search and rescue operations, and guiding post-disaster reconstruction efforts. In countries like Brazil, Colombia, Haiti, Peru, and Nicaragua, community groups have been trained to use UAS to help perform humanitarian mapping in complicated places, aiding rescue efforts at disaster sites. Examples include the use of community drones after the 2020 hurricanes in Nicaragua; in 2021, drones helped to assess damage and do mapping after the earthquake in Haiti; and community drones were used to assess damage and landslide risk after the 2022 floods and landslides in Rio de Janeiro, Brazil (Vargas-Ramírez and Paneque-Gálvez, 2019; Sánchez-Zuluaga et al., 2023; Flying Labs, 2023, n.d.).

Community drones extend their impact beyond environmental and disaster management, serving as catalysts for social development. Engaging with drones provides communities with a gateway to broader technological knowledge and exposes them to digital data collection, analysis, and interpretation. Community drone initiatives can help generate employment opportunities in UAS piloting, cartography, data analysis, and UAS maintenance—particularly in underdeveloped and geographically isolated regions. By equipping communities with valuable technical skills, community drone programs help narrow the technological gap and fostering participation in the knowledge economy (Paneque-Gálvez et al., 2017; Vargas-Ramírez and Paneque-Gálvez, 2019). Two program examples are: the Flying Labs Initiative trains young people from vulnerable communities across 11 LAC countries in drone operation and data analysis; the Humanitarian OpenStreetMap Open Mapping Hub LAC with its active promotion of mapping practices in the community (Flying Labs, n.d.; Humanitarian OpenStreetMap, 2023). Community drones in Latin America represent a paradigm shift as they empower local communities to address critical challenges related to climate change, disaster risk reduction, and social development. By harnessing the potential of UAS, a more resilient, sustainable, and equitable future can be created for the region. Supporting these initiatives authorizes often marginalized communities to effectively collect data, share their local knowledge, and actively participate in shaping their destinies. Furthermore, community drones help reduce risks faced by environmental defenders and fostering a more inclusive and effective environmental governance (Paneque-Gálvez et al., 2017; Vargas-Ramírez and Paneque-Gálvez, 2019; Duffy et al., 2020; Spina Avino et al., 2022, 2023).

6

Moving Forward: Findings and Recommendations

Explore the promising potential of drones to aid governments in achieving development objectives across LAC. While private sectors, particularly agribusiness and mining, have driven adoption, significant disparities exist due to prohibitive regulations. The public sector plays a critical role in fostering UAS ecosystems. There is a need for balanced regulations, improved institutional capacity, and increased awareness to unlock the full benefits of drone technology.

6.1. Conclusions

Recent use cases demonstrate that unmanned aircraft systems (UAS) have strong potential to support governments in achieving development objectives. It is a constantly evolving technology that has been tested with promising results worldwide and is worth continued exploration into how this technology can be applied.

In LAC, the level of adoption has been mainly driven by private companies in the agribusiness and mining sectors, but the degree of usage trails the best practitioners internationally. A closer look reveals a disparity in the level of UAS adoption across the region. Some countries like Brazil, Mexico, and Uruguay appear to be advanced in the development of a UAS ecosystem for the adoption of drone technologies. Others, like the Caribbean countries, are lagging behind; in Nicaragua, drones have been prohibited.

Despite promising potential, UAS are in an early stage of use for applications that could help reduce the region's development gaps. There are numerous pilot projects for emergency aid distribution, delivery of medical goods, reforestation, support for small-scale farmers, infrastructure monitoring and disaster risk management, but no large-scale deployment of such applications has been launched. In this sense, the role of the public sector is crucial in driving the development of applications. Nevertheless, there appears to be a certain lack of capacity, institutional coordination, and incentive to encourage the emergence of such uses.

The development of drone ecosystems could bring many new jobs and attract private sector investment. However, this development is limited by several barriers: the need to improve the regulatory framework; the lack of technical and institutional capacity; limited public awareness of UAS benefits; the complexity of the business environment and public procurement systems; and the absence of funding for innovation. In this sense, the public sector has a key role to play in creating the environment needed for the drone industry to flourish in the region. In addition, the advancement of UAS in LAC cannot be achieved without greater public sector involvement in areas like the policy development, the evolution of solid operational regulations, and the growth of well-structured UAS projects.

Balanced regulations, adapted to the needs of each country to ensure operational airspace safety and allow initiative and innovation, are key to the development of UAS in the region. At present, two of the 35 countries surveyed have advanced regulations, 22 are in the initial or intermediate stages and require regulation improvement. In the Caribbean region, 11 countries have yet to introduce UAS regulations. The public sector should consider that further development of these regulations and planning for the means to operate and enforce them, will be key issues for the development of UAS ecosystems in LAC.

6.2. Moving Forward

An overview of the state of drone implementation in Latin America and the Caribbean led to the identification of a list of lessons learned, and recommendations, for continuing to promote the development of UAS technology in the region. Here are the main lessons learned from this work.

1. **UAS development strategies at national level should follow a holistic approach.** The use of UAS for development is based on several dimensions that go beyond purely technical aspects and involve a wide variety of players. It requires a holistic approach with a well-functioning regulatory framework, digitized processes, aware stakeholders, a well-educated workforce, innovative entrepreneurs, and clear administrative structures. As an essential element of these structures, the public sector plays a key role in defining policies for implementing such an approach. Given the novelty of the innovation, the complexity is often difficult for public players to grasp, and they struggle to define roadmaps that take all the elements into account. To address this complexity, and cover all the elements mentioned, it is advisable to follow the conceptual framework shown in Appendix 4.

2. **Strengthening regulations that are tailored to each country's context is crucial to boosting the development of UAS in the region.** The development of UAS regulations in the various LAC countries is a priority to encourage the development of UAS in the region. As discussed in Chapter 3, it is important that the regulations are adapted to the climate of each country and that they strike a balance between ensuring safety and fostering innovation. The regulations should be flexible enough to evolve alongside technological advancements and different use cases. In this effort, LAC countries can rely on the International Civil Aviation Organization (ICAO) or regulatory agencies such as the European Union Aviation Safety Agency (EASA) or the Federal Aviation Administration (FAA) for technical assistance. International institutions such as the World Bank can also help. It would also be advisable to encourage cooperation and exchange between the different countries in the region. Besides, harmonizing regulations in the medium term between the various LAC countries, it would, at least on a sub-regional scale, facilitate the broader development of UAS applications and encourage synergy.

3. **The implementation of UAS applications should be based on a comprehensive needs assessment.** Implementing UAS solutions simply for the sake of bringing a new technology, without addressing the intended need, is of limited interest and will ultimately erode the perception of the technology's usefulness. UAS should not be seen as an end, but rather as an additional tool to be incorporated into existing processes, or as a means of providing capabilities that were not previously available. For the public agency, it is important to start from the definition of the need, identify where current resources are lacking, and then analyze the extent to which a UAS solution can provide an answer. If UAS is in competition with a traditional method, it will be necessary to assess whether UAS adds value, whether its use is justified. This process involves identifying the challenges, requirements, and opportunities in the public sector where drone technology can make a meaningful impact.

4. **To capitalize on knowledge gained, pilot projects should include frameworks for results to better assess UAS value compared to traditional methods.** The use of pilot projects to gradually familiarize members of the public sector with UAS technology seems advisable. Pilot projects are employed in LAC, however, to take full advantage of the experiences, it is crucial to accompany them with results frameworks to better measure their impact. This involves establishing clear metrics and indicators to assess the value for money of UAS compared to traditional methods. The goal is to quantify the benefits and efficiencies of drone technology and allow for informed decision-making and resource allocation.

5. **Setting up a UAS application means strengthening inter-institutional coordination.** Most UAS applications require the participation of various public stakeholders. It is key to have a clear division of roles and set up inter-ministerial coordination units. In the region, it is often observed that the various ministries work on UAS solutions in silos, considering only their sector. It would be far more beneficial to articulate these initiatives and take advantage of cross-sectoral feedback. For example, a medical goods delivery project that requires beyond visual line of sight (BVLOS) operations will require the technical support not only of the civil aviation authority, but also of the ministry in charge of public health infrastructures.

6. **Capacity building is key to increase public sector awareness and acceptance.** Lack of institutional capacity is identified as one of the main barriers to the development of UAS. A better understanding of UAS applications by the public sector, and their successful implementation, will require a major, coordinated public sector training effort. This includes training government personnel on drone operations, data analysis, and interpretation. Strengthening the skills of public sector employees will enable the integration of drone technology into workflows and processes.

7. **Governments can rely on several partners to support unlocking the potential of UAS for development.** The public sector can draw on financial institutions such as the World Bank and on a large network of NGOs in the region that support the development of UAS. The private sector may also be interested in capacity development and has proved to be collaborative in this area. In addition, it would be appropriate to encourage exchange between country-level administrations in the region, which can mutually benefit from sharing experience and knowledge. Finally, it would also seem important to involve academic institutions in this training process, and plan specializations and curricula dedicated to the use of UAS.

6.3. World Bank Drone Engagement in the Region

Drones are a reality for World Bank operations, not only in remote supervision and implementation support for Project Implementation Units, but also introduced as part of the project activities. Some examples of executed work are the use of drones for environmental monitoring in the Tocantins Regional Sustainable Development Project and the use of drones for right of way monitoring in the Bahia Road Rehabilitation and Maintenance Project (2nd phase).

In addition, other projects are under way with projects that will use drones for infrastructure monitoring in Guatemala, El Salvador, Brazil, Peru, and so on and for agriculture support for family farmers in Brazil and other countries. This work showcases that the World Bank can be a strong ally of LAC governments willing to introduce and scale up the use of the drone technology and that projects can be one of the best ways to introduce, and reinforce, the need for technical knowledge, regulation, and institutional capacity.

A

Appendices

Appendix 1. Overview of UAS Solutions

Without claiming to be comprehensive, this appendix aims to define some basic concepts of drone operations and give a sense of the wide variety of existing solutions.

Overview of Unmanned Aircraft System Types

Innovation in the Unmanned Aircraft System (UAS) sector has resulted in a wide variety of models, which is only increasing as new applications are developed. The purpose of this section is to provide a brief overview of the most common types of UAS for commercial use and their general technical characteristics. This description is by no means exhaustive and is intended to provide the reader with a basic understanding of this report. There are four main types of commonly encountered UAS.

Multirotor UAS

A multirotor drone (Figure A1.1) is a type of UAV that has multiple motors that drive the propellers to take off and maneuver the aircraft. They work on the principle of the helicopter, offering hovering and vertical takeoff and landing capability. Their versatility makes them a much-used model, especially for image capture. Some models are also equipped with a carrying capacity of up to 25 kilograms.

Figure A1.1. Illustration of a Multirotor UAS

Application: Transport, geodesy, aerial photography and videography, inspections

Characteristics: Vertical take off and landing, flight stability, possibility to configure hoovering, manoeuvrability

Lifting capacity: Up to 25kg

Flight time: Up to 1h

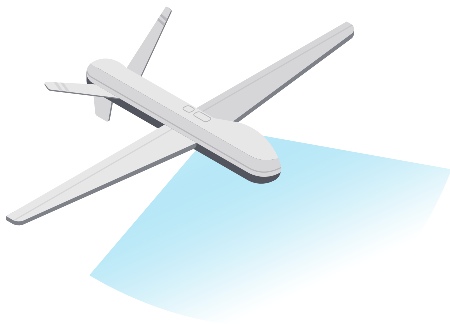
Range: Up to 10 km

Source: PwC 2023.

Fixed-Wing UAS

Fixed-wing UAS (Figure A1.2) operate on the same principle as traditional aircraft, with a rigid wing providing the necessary lift. The energy supplied by the motors is therefore used for propulsion, not to maintain the aircraft's lift. This makes them an energy-efficient solution that can cover longer flight times and distances than a multirotor, making it well suited for large area mapping tasks. Fixed wings do, however, require a launch infrastructure, usually a propulsion ramp and a landing device.

Figure A1.2. Illustration of a Fixed-Wing UAS



Application: Aerial mapping, inspections of widespread areas such as pipelines and power lines, security, BVLOS flights

Characteristics: Long endurance, large coverage area, fast flight speed

Lifting capacity: Up to 5kg

Flight time: Up to 7h

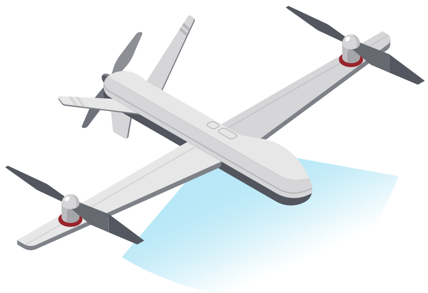
Range: Up to 600 km

Source: PwC 2023.

Vertical Takeoff and Landing UAS (VTOL)

VTOL are hybrid fixed wings and multirotor UAS that combine the benefits of both designs (Figure A1.3). They have rotors attached to the fixed wings, allowing hovering and vertical and horizontal takeoff. This advanced technology is already in use, demonstrating its versatility across various applications. It is particularly beneficial in areas where space or infrastructure for traditional fixed-wing drone operations is limited. VTOLs excel in missions requiring both long-distance travel and precise hovering, such as with goods delivery or surveillance.

Figure A1.3. Illustration of a VTOL UAS



Application: Agriculture, natural environment protection, mining, package delivery

Characteristics: Vertical take-off and landing, long endurance, fast flight speed

Lifting capacity: Up to 10kg

Flight time: Up to 2h

Range: Up to 60 km

Source: PwC 2023.

Tethered UAS

A tethered UAS provides power and communications to a UAV using a permanent physical connection in the form of a flexible wire or cable (Figure A1.4). These systems enable a particularly high flight time and are suitable for certain types of application where one specific spot is monitored for extended periods, such as with public safety, surveillance, or safety missions. They are also starting to be used as flying cellular towers to provide communication in remote areas or in case of emergency. They generally rely on multirotor UAVs as they need hovering capacity.

Figure A1.4. Illustration of a Tethered UAS

Application: Public safety, surveillance, portable communication, safety mission

Characteristics: Attached (tethered) via a physical link to a person, the ground or an object at all times while it is flying

Lifting capacity: Depends on the type

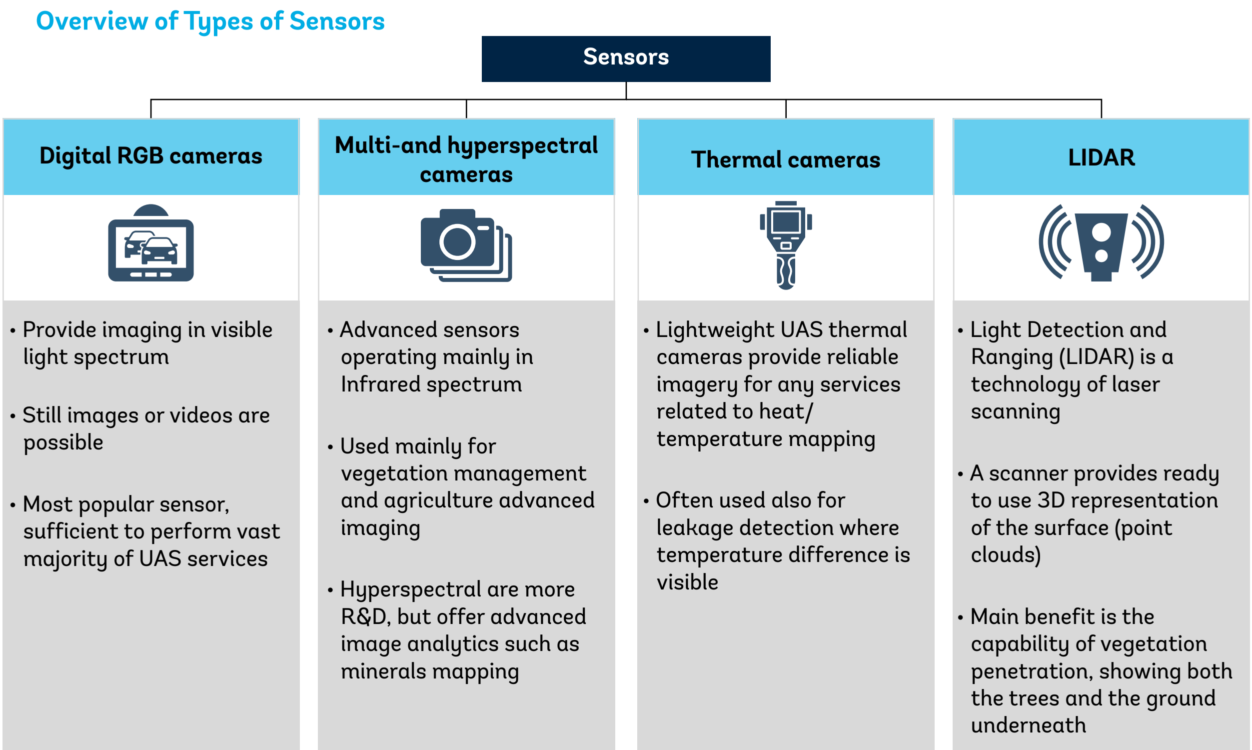
Flight time: Up to 24h

Range: Depends on the type

Source: PwC 2023.

In addition, there are an infinite number of variations and customizations to adapt them to different applications. Common adaptations include the use of spraying equipment for fertilizer and pesticide spraying in the agricultural sector, platforms for the transport and delivery of goods, and the use of sensors for data capture and analysis. For this reason, it may be useful to present the four types of sensors frequently used in UAS (Figure A1.5).

Figure A1.5. Sensors Commonly Used in UAS



Source: PwC 2023.

It worth mentioning that drones can be powered by a variety of energy sources, each with its advantages and limitations:

- **Electric-powered drones** are based on battery usage and are easy to recharge, but have limited flight times. If they are powered by carbon-free electricity, their operation can be Greenhouse Gas (GHG) emission-free.
- **Gasoline-powered drones** offer extended flight times but may be noisy and heavy and contribute to GHG emissions.

  Fuel-cell powered UAS are based on hydrogen (H_2) and can be an interesting alternative as they allow extended flight time with zero emissions. In the case of using green hydrogen, the operation can be considered carbon neutral. However, green hydrogen is not yet available on a large scale and it is difficult to foresee widespread use of such UAS in the short term.

Operational Concepts

To facilitate the understanding of this report, it may be useful to introduce some of the concepts related to the operation of drones (Fixar, 2022).

Visual line of site (VLOS): A VLOS operation (Figure A1.6) is one in which the remote pilot maintains direct unaided visual contact with the remotely piloted aircraft. This means that the UAV must remain clearly visible during the entire flight without any additional equipment, such as binoculars.

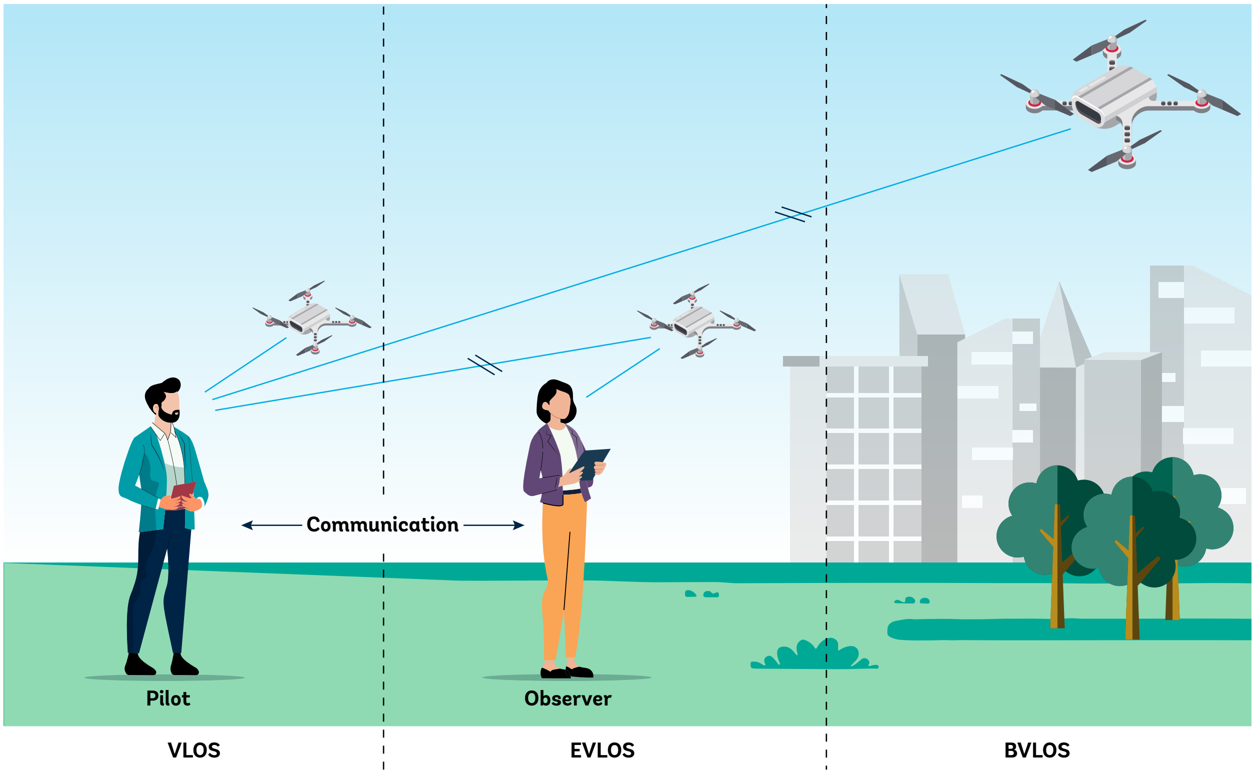
The maximum operating distance is therefore defined by a visibility criterion and may vary according to visibility and lighting conditions. This usually corresponds to short distances in the order of 500 meters.

Extended visual line of sight (EVLOS): An EVLOS operation allows the range of operation to be extended by using one or more additional observers who maintains visual contact with the UAS and communicate and alert the pilot if necessary.

Beyond visual line of sight (BVLOS): In this mode, the pilot has no direct visual contact with the UAV. This corresponds to cases where drones are used over long distances and the pilot controls them remotely from a control station. In practice, this type of operation involves a high risk of interference in airspace. Such uses in the civilian sector need to be tightly controlled and are still prohibited in many countries, notably in the United States, where they have yet to be regulated.

First-person view (FPV): FPV, also known as remote-person view (RPV) or video piloting, is a method used to control an UAS using a viewpoint derived from an on-board camera or other visual information device. In FPV, although remotely positioned, the pilot experiences an onboard-the-aircraft view through a camera feed transmitted to goggles or a monitor. This feature is applicable to both fixed-wing and multirotor aircraft. FPV may be used in a range of UAS applications, most commonly for recreational purposes or filmmaking. As the use of FPV does not provide complete awareness of the surroundings of the aircraft, it should be considered as BVLOS, unless an additional observer supports the pilot. In such a case, they would fall under EVLOS.

Figure A1.6. VLOS, EVLOS, and BVLOS concepts



Source: PwC 2024.

Appendix 2. Overview of UAS Adoption by Country

Each country in the LAC region has a unique set of challenges, constraints, and opportunities when it comes to the adoption of UAS. They have their own political, economic, and social landscape, with drone ecosystems in various stages of development. This appendix gives an overview of the countries covered in the study, broadly divided based on their location: North America, South America, Central America, and the Caribbean.

North America

Mexico — the only Latin American country in this region — has a UAS ecosystem that can be classified as intermediate development. The country's market for UAS services has shown consistent growth and companies that involved with agriculture, construction, energy, mining, and the security sectors have already implemented the technology into daily activities (including data science and AI solutions). To move from an intermediate stage of growth to an advanced one, Mexico needs to make progress on regulation relating to the digitization of elements like airspace maps, a regulatory framework for robust BVLOS, and an automated flight authorization process. The insurance component of the ecosystem also needs attention (PwC, 2021a).

A large presence of international companies makes drone technology easily accessible in Mexico. While international drone manufacturers and software developers supply technology to Mexico, the number of offers from local technology providers is limited. Around 2013, a relevant number of local drone companies were started, but subsequently closed because of insufficient funding and not enough interest from potential customers. To strengthen the position of local companies, Mexico needs initiatives that support the creation of reliable and scalable drone solutions. An example of an initiative was the announcement in 2013 by Mexico's secretary of agriculture that the country would use drones to monitor crops (AS/COA, 2013). Startups that produce drones for agricultural use cases have begun to thrive in the market and have benefitted from high levels of demand.

A few initiatives in other sectors include a 2015 research project that showed how UAVs can be applied in the Mexican infrastructure industry to determine the conditions and characteristics of a road, its gaps, landslides, fallen trees, type of traffic, presence of animals, and atmospheric conditions (Obras, 2015). Another company announced its desire to provide autonomous passenger drone tours along the coast and is in the process of applying for permission to fly in Mexican airspace (Yucatán Magazine 2022). This shows that Mexico is relatively progressive in its approach to urban air transportation and that it aims to enable advanced air mobility[13] for passenger transportation.

Although the regulations are among the most advanced in LAC, there are some restrictions that are limiting the current UAS development potential. This includes constraints on BVLOS operations and a prohibition of drone operation levied against non-Mexican citizens. Digitization of drone-related processes is limited with the sector relying on paperwork and traditional methods of communication between authorities and pilots. Consequently, Mexico's level of digital readiness needs to be improved to support further ecosystem development and use case adoption (PwC, 2021a).

[13] Advanced Air Mobility (AAM) refers to the development and deployment of new aviation technologies and systems to create efficient, automated, and integrated air transportation solutions within urban and regional environments. This includes the use of electric vertical takeoff and landing (eVTOL) aircraft, drones, and other innovative air vehicles to transport passengers and cargo

South America

There is a wide variety of UAS ecosystem development among the 12 countries in South America that are a part of this research. However, the presence of official drone regulations across most of the countries on the list makes it a promising hub for drone technology.

Brazil leads the region—and LAC as a whole—due to having well-established drone regulations and a large local market, especially for agricultural applications. The country has strong adoption rates and highly accessible technology thanks to the presence of international players and a broad range of local manufacturers. Some of the Brazilian universities offer drone hardware to allow students to experiment with emerging technology and some of institutions already offer full-fledged post-graduate specializations in UAS. Recent updates to the SARPAS NG UTM system[14] continue to accelerate the development of the drone ecosystem by providing more efficient and automated flight registration for remotely piloted aircraft (DECEA, 2022). This, combined with a high level of digital readiness, has the potential to improve the industry's prospects across the country.

Uruguay has a comparatively high level UAS ecosystem, as well as a developed UTM application featuring a basic set of services that has been accepted and deployed by the civil aviation authority. While the regulatory framework still needs to be updated to unlock the potential of the UTM system, the country has taken major steps toward the digitization of lower airspace. Uruguay has a wide range of ongoing drone projects in different industries (agriculture, safety and security, infrastructure) and strong initiatives supporting and financing the industry that will positively influence the expansion of the Uruguayan drone ecosystem (PwC, 2023).

Colombia's drone ecosystem has seen accelerated growth over the last five years and is seeing relevant progress in terms of its technological development. The potential lies in expanding the current drone regulations to enable more advanced use cases. Although the Colombian drone regulations may seem restrictive, they allow for the authorization of BVLOS operations and various other experimental actions. Several projects involving BVLOS operations are happening in the country, and Colombian drone operators are starting to use UTM systems to manage the volume and complexity. Two companies have been instrumental in developing these systems. One is Inter Rapidisimo, which aims to be the first drone courier in the country (Forbes, 2022). The second is ORKID, a drone delivery startup that developed autonomous delivery drones and has been testing BVLOS flights under the surveillance of the Colombian Civil Aviation Authority, the Colombian Air Force, and the Ministry of Transport (SUAS News 2022). Innovations like these and further investment into UTM systems can bring flight authorization times down from Colombia's current benchmark of 15 days. This can make a significant difference to the adoption of the technology (Colombian Civil Aviation Authority 2015).

Argentina, Bolivia, Chile, Ecuador, Guyana, Paraguay, Peru, and **República Bolivariana de Venezuela** have all managed to establish official regulations that are quite comprehensive, which bodes well for the trajectory of the ecosystem. Although the drone ecosystems in these countries are at intermediate levels of development, the regulations are expanding to allow for more advanced use

[14] SARPAS NG UTM stands for "Solicitação de Acesso de Aeronaves Remotamente Pilotadas Next Generation" (Request for Access of Remotely Piloted Aircraft Next Generation) and "Unmanned Traffic Management." It is a system designed to manage the safe and efficient integration of drones into the airspace. The system facilitates more efficient and automated flight registration for remotely piloted aircraft, thereby accelerating the development of the drone ecosystem.

cases like BVLOS flights, cargo deliveries, insurance assessments, and environmental monitoring, among others. This expansion should lead to an ecosystem that is progressive and conducive to innovation (PwC, 2021a).

Suriname, on the contrary, is at a preliminary stage of regulatory development. The country is currently following an official guidepost stating the partial prohibition of drones with the possibility of flying under permission granted by the Minister in charge of air transport (CASAS, 2019).

In terms of South American use cases, commercial use of drones has already been established across industries such as agriculture, mining, forestry, and construction, among others. Agriculture has seen the most adoption and continues to lead the way in demand for drone technology. In Colombia, for example, the primary function of UAV is crop fumigation, which is carried out in a controlled way, greatly reducing the risk of contamination of the surrounding ecosystems, environment, and communities. The efficiency of the drone technology results in the contamination reductions thanks to its directed fumigation capability (Embention, 2022). In Brazil, the accurate mapping of cultivation areas is an important precondition to help with field management and yield forecasting that is crucial to achieving true precision agriculture. Crops are sensitive to sowing patterns and have a limited capacity to compensate for absent areas in a given row, which negatively impact the yield per unit of soil area during the harvest time (Embrapa, 2021).

Examples from other industries include road infrastructure projects in Brazil, where drones are used to verify the need for maintenance or reconstruction. They are also able to determine whether roads were built according to the agreed-upon specifications (Cardoso Parente, Carvalho Felix, and Pessoa Picanço, 2017). In the safety and security industry, police in rural Uruguay are using drones to combat cattle rustling (InSight Crime, 2021) and drug and gun trafficking. With this implementation, police aim to tighten response times and have wider coverage of all areas (Infobae, 2022).

Central America

For the seven Central American countries in this report, most drone ecosystems are characterized as early stage development with Panama and Guatemala leading in adoption. At this level of development, different use cases have been implemented, some permanently, but most are pilot projects rather than full-scale applications. In addition, the regulatory environment does not yet allow for more complex and nuanced drone use cases that would be common in more advanced ecosystems. Lastly, the user demand and awareness around drones is still at an early stage with lots of potential for growth (PwC, 2023).

Costa Rica, El Salvador, Guatemala, Honduras, and Panama have drone regulations at an intermediate stage of development. Notably, even with basic regulatory frameworks, BVLOS operations are allowed in Guatemala and Costa Rica with special permits (PwC, 2021a). The drone regulations of Belize are at the early stage of development, whereas in Nicaragua, drones have been prohibited since 2014 (Nicaraguan Institute of Civil Aeronautics, 2014).

Panama is a regional example of a well-developed ecosystem with digital drone registration, state-of-the-art drone training through platforms for virtual education, and a government-sponsored cluster of academic organizations, technology companies, and non-governmental organizations housing drone companies (Autoridad Aeronáutica Civil, n.d.; Drone e-Learning, n.d.).

Guatemala was the first country in the region to introduce drone regulations back in 2013, and because of that distinction, is regarded as a pioneer (DGAC Guatemala, 2022). Currently under review, the regulatory framework needs to be updated to enable wider digital transformation, easier registration processes, and more advanced tracking. These updates are crucial to enable the transition of an ecosystem from an early stage of development to a more advanced stage. If these regulatory changes occur, Guatemala's drone ecosystem will be able to expand into many industries where the technology can play a major role (PwC, 2023).

Costa Rica is an example of a country that does not have a dedicated drone training program, but they do have an aviation school that offers drone courses (AENSA, n.d.). This is an alternative approach to having an official and professional drone education supporting the industry. The existence of the school should enable a wider knowledge transfer that could lead to improved progress in terms of the ecosystem's development. Other countries lacking drone training companies could follow this example to invest in education and awareness (PwC, 2023).

In Central America, use cases have been adopted across a variety of industries—agriculture, forestry, nature preservation, environmental monitoring, mining, construction, and other sectors. In Guatemala, agricultural drone operations started in early 2010 and their use for crop protection, fertilization of coffee crops, and fertilization of sugarcane remains strong to this day (Prensa Libre, 2015; AGG, 2015). Applications in forestry, nature preservation, and environmental monitoring are noted in Costa Rica, Panama, Guatemala, Belize, and El Salvador. Drones in Panama are deployed in the mining and construction industries (PwC, 2023).

Guatemala is introducing the use of drones for road safety and monitoring (PwC, 2023). The police in that country use drones for the surveillance of suspected criminals through targeted localities and the monitoring of properties to be searched. Drones are used for the same purpose in Belize and Honduras, where the technology is expected to have a significant impact on safety improvements.

Caribbean

Across the 15 Caribbean countries analyzed in this report, there is a clear upward trend in drone awareness and adoption. At present, most use continues to be associated with recreational activities, while commercial application is still in its early stages. As such, the region's ecosystem is in an early stage of development when it comes to adoption. Many Caribbean countries do not have fully-fledged regulatory frameworks. This should be a priority because a robust framework is the first step towards relevant growth in the drone industry. Once a more comprehensive framework has been established, numerous steps can be taken to accelerate the region's digital transformation, including the digitization of airspace maps, improved registration processes, and the reduction in flight authorization times (PwC, 2023).

Although local drone service providers and technology resellers are present in the countries, local hardware manufacturers or software developers have not been identified. UAS operators in the Caribbean are primarily divided into two main categories: those that originate and operate in Caribbean countries, and those that are from outside of the region but operate in at least one Caribbean country. International UAS operators contracted for disaster relief efforts and community or environmental development are typically hired for a specified period.

Despite the proximity of the countries, and the existence of the Eastern Caribbean Civil Aviation Authority, each country tends to follow its own set of regulations. Therefore, there is no unified Caribbean approach to drone regulation.

The regulations in Antigua and Barbuda, the Bahamas, the Dominican Republic, and Trinidad and Tobago stand at an intermediate level, which makes them the most well-developed countries in terms of drone regulations in the Caribbean. Of the largest countries by population, Jamaica's drone regulations are at an early stage of development and Haiti has not yet established official drone regulations (PwC, 2021a).

The Caribbean is prone to natural disasters, so a vast number of drone use cases in the region are related to disaster relief, preparedness, and mitigation. The first known UAV disaster relief use case came in 2012, two years after a massive earthquake struck Haiti. Medications and blood deliveries were made (Medscape, 2013) and later that year, drones were used for camp management, post-earthquake censuses, and damage assessment after flooding caused by heavy rains. Other institutions and organizations have deployed drones to assess damage after hurricanes in Dominica, Puerto Rico, and after volcanic activities in St. Vincent and the Grenadines (PwC, 2023).

Likewise, several medical goods delivery pilot projects took place in the Dominican Republic, aimed at the feasibility of drone cargo delivery in rural communities and hard-to-reach areas such as the remote mountains of the country (The Guardian, 2013; WeRobotics, 2019). Similar projects happened in the Bahamas, where the delivery of cold-chain medicines and vaccines between islands was tested (DirectRelief, 2019).

Drones are also used to map coral reefs in the Caribbean (Cool Green Science, 2014) and to combat illegal fishing in Jamaica (The Fish Site, 2015). In Barbados and the Eastern Caribbean, UAS technology is used to monitor and map sargassum influxes, assess and manage the impact on fisheries, and improve adaptation to sargassum influxes across the region (DroneDeploy, 2021).

Appendix 3. The Importance of Drone Regulations

Drone regulations serve a dual purpose. They facilitate the seamless integration of drones into the existing aviation system in a safe and proportionate manner, while fostering a competitive and innovative drone industry. These regulations set essential safety and environmental protection standards, aligning them with societal expectations and safeguarding public interests, including privacy and security. Moreover, regulations need to provide the necessary flexibility for the industry to evolve, innovate, and mature. In doing so, these regulatory measures ensure that the wide range of drones and their applications are effectively addressed. The regulatory framework acts as an enabler, striking the vital balance between promoting innovation and addressing societal concerns related to safety, environmental conservation, privacy, and security.

Regulations tailored to the conditions of each country are essential to ensure the readiness and effective deployment of UAS applications. Drones can serve as invaluable tools to address the challenges of the region. To harness this potential, it is important that regulations take the needs of each country into account in a practical and realistic way. Above all, the aim is to provide a practical framework for action that guarantees the safety and security of all, while also giving users the guidance they need to operate to that end. It is crucial to underscore the importance of addressing the institutional capacities of the regulator and the capacities of all ecosystem participants who must foster funding mechanisms and bridge skill gaps while remaining aware of the broader context and the characteristics shaping each country's drone ecosystem and regulatory landscapes. For instance, in the case of UAS for disaster risk management, well-crafted regulations that include emergency and state operations are essential for coordinating efforts among stakeholders. Regulations ensure that the required skills and processes are in place for the use of drones in pre- and post-disaster scenarios and enable rapid, coordinated deployment in the event of a disaster.

Different standards and approaches are used for the development of drone regulations. Some come from manned aviation, while others are created solely for UAS operations. To design, develop, and write regulatory framework for UAS operations, there are two main standards: operation-centric and risk-based (for conceiving and evaluating drone operations). Similarly, there are two main approaches for writing the regulations: performance-based and prescriptive. While the risk-based standard is present in manned aviation, the operation-centric approach was specifically developed for regulating drone operations because they are unmanned (Box A3.1).

The operation-centric standard is holistic by nature, and aims to address design, maintenance, operations, personnel licensing, aerodrome and airspace matters. This is unlike the regulation of manned aviation, where those elements are handled by separate regulations. The operations-centric standard underlines the role of the UAS operator and its personnel. However, it does not prevent imposing obligations on other players like manufacturers to obtain, for example, Class Markings for their drones. The relevance of this standard is that the focus is on the type of operation being conducted, rather than who is conducting it or why it is being done. Since there is no one on board the aircraft, the consequences of a potential accident are dependent on where the UAS operation take place. The operation-centric principle is mostly related to low risk (open) and medium risk (specific) categories, while the certified category, which foresees operations at high risk, should be regulated like manned aviation (Future Learn, n.d.).

The risk-based standard aims to regulate UAS by thoroughly identifying associated risks and defining use conditions accordingly. This standard seeks to confine UAS operations to specific applications, guided by rules crafted to effectively mitigate risks. Various factors, including operational location, drone type, and flight purpose inform these regulations. They categorize operations in different risk levels, enabling tailored rules and restrictions. For example, densely populated urban areas may enforce stricter regulations and no-fly zones due to heightened risk, while rural areas may have fewer restrictions. The level of regulatory scrutiny is determined by the potential risk to safety, security, and privacy. Operations with higher risks may require stricter protocols, promoting an efficient allocation of regulatory resources. Tailored regulations avoid a one-size-fits-all approach, accommodating the diverse profiles of operations (EASA, 2015).

The prescriptive approach specifies requirements for mandatory methods of compliance and defines rules that are clear. The measure of accomplishment is relatively straightforward with respect to the fact that it is a “yes” or “no” situation. Prescriptive regulations define strict operational and technical requirements that cannot be exceeded without exemptions. Limitations could be applied to the weight, size, and speed of the unmanned aircraft as well as to the altitude and the area where the operation is executed. The focus is not on achieving the desired performance and the outcome of the operation, but rather on the way requirements are fulfilled (Anderson et al., 2023). Experience has shown that simple compliance with prescriptive regulations does not guarantee safety. Moreover, this approach can narrow possibilities for diverse drone operations, limiting new technology advancements, and the use of emerging applications.

The performance-based approach, rather than creating a set of prescriptive operational rules, aims to identify the required capabilities or levels of performance for various UAS applications using different technical solutions, provided they meet the desired performance and safety criteria. This approach focuses on desired, measurable outcomes instead of fixating on specific methods or technical solutions. For instance, regulatory bodies might mandate that all drones include collision-avoidance systems, remote identification capabilities, or adhere to specific weight limits. It is the responsibility of drone manufacturers and operators to ensure that their drones comply with these technical performance standards. This approach provides flexibility for drone operators to adapt their operations to meet technical safety requirements, while accommodating technological advancements and innovation in the industry (Drone Alliance Europe, 2016).

Defining the right style of regulation is crucial to the sector’s development. Overly prescriptive regulation will limit use cases and allow little innovation, while regulation based solely on performance may ignore important security risks. For this reason, regulations need to provide the right balance between operations and legal certainty (see Box A3.1). These principles and approaches to UAS regulations are present at different levels and combinations across benchmark regulatory frameworks and model regulations such as the UAS regulations of the European Union Aviation Safety Agency (EASA), the International Civil Aviation Organization (ICAO) model regulations, the Federal Aviation Administration (FAA), the Brazilian National Civil Aviation Agency (ANAC), Rwanda Civil Aviation Agency (RCAA) and many others.

Seven fundamental parameters can serve as a guide for assessing drone regulations to ensure operational safety, legal certainty, and industry growth. These parameters have been identified by analysis of international best practices and in consideration of benchmark countries that support UAS regulatory frameworks. They can be used to highlight crucial aspects when designing, writing, analyzing, and implementing UAS regulatory frameworks (Figure A3.1). These include various dimensions: comprehensive regulations, the incorporation of performance-based elements, and an operation-centric approach. Furthermore, they must address safety, security, privacy, and environmental concerns, while striving for simplicity in their design. Additionally, regulations should require that proportional resources for authorities and stakeholders are applied correctly. Lastly, regulations should be developed and adopted using an open and transparent process. By adhering to these parameters, drone regulations can better foster a conducive environment for safe and sustainable UAS operations while supporting industry growth.

Figure A3.1. Most Relevant Parameters of UAS Regulatory Assessment

Basic parameters of regulation assessment	
1 |	**Comprehensive** Allows maximum types of drone operations and does not restrict activity
2 |	**Performance-based** Facilitates the quick adoption of rapidly-growing drone technology
3 |	**Operations-centric and risk-based** Accounts for the complexity and characteristics of UAS operations, depending on the geographic and airspace environment
4 |	**Safe, secure, environment-conscious, and privacy-focused** Addresses these four elements to increase acceptance of drone operations by the public
5 |	**Simple** Creates easy-to-understand regulations to increase implementation success and reduce risk of misinterpretation
6 |	**Resource-conscious** Ensures proportionate resources for authorities and stakeholders and balances expected safety benefits and the cost of implementation
7 |	**Transparent** Develops and adopts regulations using open processes to drive acceptance of proposed rules by stakeholders and the public

Source:

Creating effective regulations extends beyond the technical aspects of drone operations; it necessitates consideration of the entire ecosystem, along with securing buy-in from all relevant stakeholders. The significance of drone regulation is multifaceted, encompassing a range of crucial elements that are aimed at ensuring safe and responsible UAS operations. These operations typically include requirements for the registration of both operators and drones, as well as the set-up of operational limits (altitude and distance) for flights. Additionally, regulations often define no-fly zones, covering sensitive areas like government buildings, hospitals, or military facilities. Many countries also require drone operators to obtain licenses, certification, and insurance promoting their competence and accountability (figure A3.2). In addition to technical aspects, evaluating internal factors like institutional capacity, funding availability, capacity building, skill gaps, and human resource availability becomes central to building a strong regulatory framework. The generation of a framework creates the opportunity to build capacity across institutions and people, produces new sources of employment and fosters participation in local training programs for operators and technicians, for example. Other critical elements for drafting regulations include context and timeframe—factors related to each country's socioeconomic, institutional, and geographical dynamics.

Figure A3.2. Typical UAS Regulatory Framework Elements

Examples of regulatory framework elements

Licensing	Assign a permit/license/ certificate and a reference number for all drone operators and pilots
Training and Testing	Provide theoretical and practical training sessions for drone pilots
Security Check	Assess new applicants to determine whether they represent a national security risk
Drone Registration	Register the drone and have an identification number displayed on it
Insurance	Ensure a liability insurance coverage in terms of damage to third parties
Conditions of Flight	Introduce conditions on operations (eg., VLOS/EVLOS/ BVLOS, distance, altitude) and enforce compliance
Geographical Restrictions	Define no-fly zones (i.e., prohibited areas) and enforce compliance
Flights Reporting	Authorize and receive notifications on drone flights, as well as incidents and accidents
Pilot-Drone Communication	Set frequency band restrictions
Security Protection	Obtain consent from managers and owners to fly over restricted or private property
Data and Privacy Protection	Provide information on how data or personal images should be protected

Source:

Regulations need to be enabled and enforced through intentional processes, procedures, and workflows that are transparent, and focus on accountability. These processes will require specific tools to make them effective. For example, a digital UAS registry system could be used to manage a registration process for a national territory. In addition, service levels should be defined for each process to meet the expectations of UAS companies and operators. Emphasizing safety protocols, providing training for operators, and establishing no-fly zones around sensitive areas are essential measures to ensure the safe and responsible use of drones. Addressing security concerns related to data collection and privacy is critical to cultivating public trust and fostering broader integration of drone technology across different sectors and geographic areas. Efforts to strengthen and develop drone ecosystems should focus not only on ensuring appropriate access to and adoption of technological advances, but also consider local realities. Ultimately, the regulatory framework should be one that promotes safety and the responsible expansion of drone applications.

Box A3.1. Principles Guiding UAS Regulation in the EU, and the Joint Authorities for Rulemaking on Unmanned Systems

When the first discussions about how to regulate drones started in the EU and at the Joint Authorities for Rulemaking on Unmanned Systems (JARUS), it became clear that with no one physically in the drone, there had to be a departure from the classical way of regulating manned aviation. It was no longer necessary to protect people on board. That meant that the ramifications of any drone accident would involve the location of the operation. Any accident would involve the population on the ground (as well as any activity in the airspace where the drone was flying). As a result, a new approach called *operation-centric* was created. It represents a holistic approach that applies to mostly low and mediums risk category operations and puts the emphasis on the role of the drone operator and its personnel.

Quite naturally, the operation-centric principle led to using a risk-based principle so regulations would remain proportionate (the higher the risk, the more stringent the requirements). As mentioned, the fallout from an accident impacts the area of operation. For instance, the risks of a survey operation by drone in Antarctica are much less than those of the same operation conducted over a major city. Ideally, the risks should be seen as a continuum, but because this would be difficult to manage, the idea of creating categories to for the risk-based approach was developed. They are as follows:

- *Open category:* Risk is managed by putting hard limitations, which allow operations to start without an authorization.
- *Specific category:* Risk is managed by a requirement that the operator undergo a risk assessment to obtain an authorization from the authority.[1]
- *Certified category:* Risk is managed in a classical manner by requiring the drone to have a type certificate (TC); the operator, an air operator certificate (AOC); and the pilot, a license.

Finally, turning to how to write the requirements, a performance-based approach is preferred to a prescriptive one. In practice, a combination of both has been used, mostly to ensure legal certainty. The preference for performance-based requirements is due to the speed of evolution of the drone technology.

In the EU, performance-based regulation is an approach that focusses on desired, measurable outcomes. It can be either objective-based, process-based, or performance-standard based.

- *Objective-based:* Only the objective is defined, not the means to achieve it.
- *Process-based:* Specific organizational requirements, or processes, are prescribed to enable a desired outcome.
- *Performance-standard-based:* A set of performance metrics (quantitative and qualitative) is defined; based on the set, a determination is made about whether a system is operating according to expectations.

The EU regulations rely on a combination of the first two approaches for the drones (that is, require certain functionalities—for example, identification, or a risk assessment—to be performed).

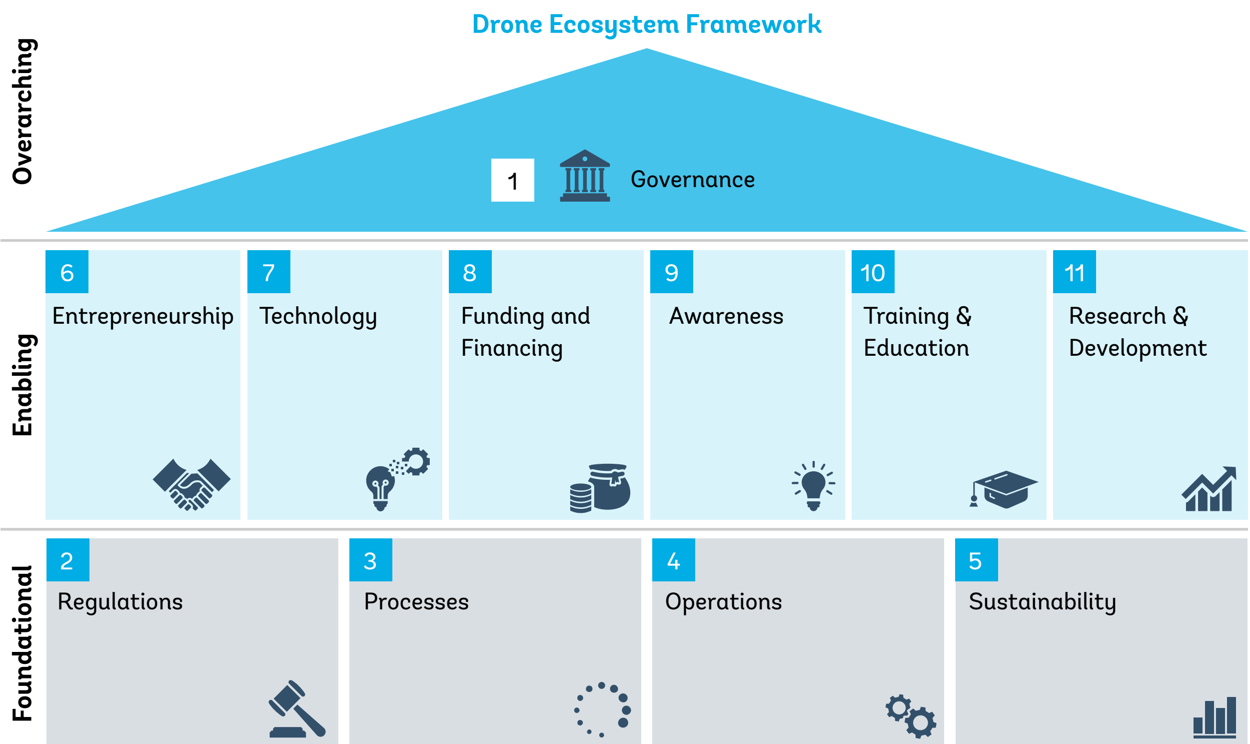
[1] To simplify the application of the requirement, alternatives such as standard scenarios, predefined risk assessments, and the optional issuance of a light unmanned aircraft operator license granting certain privileges have been offered

Source: Morier 2024.

Appendix 4. Conceptual Framework for the Drone Ecosystem

The proposed framework in Figure A4.1 defines 11 elements divided into three categories: foundational, enabling, and overarching. These elements summarize the important aspects of the long-term vision to achieve growth in the UAS sector. They are also strongly interconnected. Underdevelopment in one or more areas may limit the potential of the entire ecosystem. The public sector is at the top of this structure, overarching the other dimensions, as it plays a key role in the definition and exercise of governance. By following this theoretical framework, the public sector will be able to develop high level strategies and action plans to cover all the elements concerned and involving the relevant stakeholders: private sector, academia, regulators, research and development institutes, funders, UAS operators, NGOs, and civil society. In addition, this holistic strategy will ensure that the use of drones in the public sector aligns with broader national goals and policies.

Figure A4.1. UAS Ecosystem Development Framework



Overarching	This category has one element that integrates all the other dimensions of the UAS ecosystem

Governance

Governance can be defined as structure and processes that are designed to ensure accountability, transparency, responsiveness, the rule of law, stability, inclusiveness, empowerment, and broad-based participation. Thus, in a broad sense, UAS ecosystem governance is about the developing institutional environment, capacity and processes as well as the community culture in which all stakeholders effectively interact among themselves in a transparent, participatory, inclusive and responsive manner.

Foundational	This category has the 4 elements that create a baseline for the sustainable development of the UAS ecosystem

Regulations

The regulations are a core foundation element of the drone ecosystem. Global examples showed that an inappropriate regulatory framework is a critical barrier to the development of the entire sector. Regulations should enable and stimulate the safe introduction of new drone use cases. Regulatory framework from ICAO, FAA (US), and EASA (EU) provide good benchmarks that could be applied in other territories.

Processes

The introduction of the regulations does not mean that it can be easily executed. The practical implementation requires processes, procedures, and workflows to be developed between relevant government agencies and citizens. The processes should be transparent and accountable. In addition, service levels should be defined for each process to meet the expectations of the UAS companies.

Operations

The drone operations at scale are possible when same or all other elements of the drone ecosystem are enabled. The core requirement to fill the airspace with drones is the stimulation of the demand for UAS services within public ad private sector.

Sustainability

Sustainability is a paradigm for thinking about the future in which environmental, societal and economic considerations are balanced in the pursuit of improved quality of life. The sustainability aspects must be taken into consideration at every step of the UAS ecosystem development.

Enabling	This category includes the 6 elements that allow the development and growth of the UAS Ecosystem

Entrepreneurship

Entrepreneurs and innovators play a crucial role in developing the UAS ecosystem, identifying business opportunities, bringing to the market solutions to specific challenges, and creating jobs. Therefore, entrepreneurship should be encouraged by removing barriers and stimulating the demand for UAS products and services and enabling funding opportunities to develop and scale new technologies.

Technology

Drone technology access and the digitalisation of airspace processes are the key enablers of the UAS ecosystem. Therefore, on the one hand, facilitating access to the UAS hardware and software and, on the other hand, supporting technology development is critical. Additionally, the innovative drone use cases cannot be safely enabled at scale without digitalisation of the relevant processes such as airspace maps and flight authorisation.

Funding and financing

The flow of capital is required for entrepreneurs and innovators to develop new innovative concepts and bring them to the market at scale. In the UAS sector, it is possible to grow business operations based on drone services organically. However, the development of innovative technologies typically requires financial support. Similarly, large organisations which could benefit from the UAS technology in their operations and stimulate the demand for UAS products and services could benefit from programmes enabling them to test and validate innovative solutions such as drones.

Awareness

Building awareness about the technology, benefits, requirements, and safety is critical for the wide adoption and acceptance of the UAS technology. Therefore, it is required among all stakeholders, from public institutions, agencies and regulators, public and private sector enterprises, entrepreneurs, and the communities affected by the use of the technology.

Training and education

Availability of training for UAS pilots as well as related to other aspects such as data processing and analytics has to be enabled. At the same time, the secondary and academic education curriculum should involve elements of drone technologies to develop the human capital of the future workforce.

Research and Development

Research and development conducted at universities, institutions, enterprises, and startups is critical to solving globally and domestically relevant problems. The R&D activities require funding and should be prioritised based on the actual market needs and characteristics.

Source: PwC 2022.

Appendix 5. High-level Drone Sector Roadmap for the Region

The development framework proposed in Figure A5.1 is a universal framework that draws from local and international benchmarks that have demonstrated successful UAS adoption. Numerous interviews with drone ecosystem stakeholders across the region were also conducted. This is not a one-size-fits-all framework and must be tailored and adapted to the unique needs, circumstances, and context of each country. The roadmap for an advanced ecosystem like the one in Brazil would be different from the one in Guatemala—an intermediate stage ecosystem—and the roadmap for an early-stage ecosystem like the one in Haiti would be even more different still.

The ecosystem development plan includes five strategic pillars: regulations and processes; digitization and automation; awareness and promotion; knowledge and education; and demand and entrepreneurship. Along with 25 strategic initiatives, it serves as a foundational framework for countries and governments aiming to develop comprehensive drone ecosystem strategies. Each proposed initiative is categorized based on its impact, complexity, cost, duration, and recurrence. This categorization prioritizes the most crucial initiatives that need to be implemented to develop and strengthen UAS ecosystems.

The five strategic pillars serve as a guide for regulators, governments, and all other ecosystem participants. They allow these stakeholders to collaborate in constructing the foundational elements, as well as the most pertinent components to enhance technology adoption across sectors and developmental use cases.

Figure A5.1. Selected Drone Ecosystem Development Incentives for LAC Region

Strategic Drone Development Initiatives for the LAC Region				
1 Regulations and Processes	**2 Digitalization and Automation**	**3 Awareness and Promotion**	**4 Knowledge and Education**	**5 Demand and Entrepreneurship**
1.1 Enable a robust UAS ecosystem governance structure and coordination between governmental bodies	2.1 Utilize and integrate systems of key UAS ecosystem stakeholders	3.1 Increase awareness among the community	4.1 Offer easy access to UAS-related information	5.1 Organize business forums to match demand with supply
1.2 Design and establish clear and transparent processes	2.2 Digitalize basic services	3.2 Develop UAS-related publications	4.2 Create and certify UAS training centres	5.2 Provide funding to test and pilot UAS technologies
1.3 Develop the institutional capacities of public bodies	2.3 Digitalize advanced services	3.3 Organize events for key stakeholders	4.3 Design curriculums to support UAS-related education	5.3 Enable incubators and accelerators
1.4 Create roadmaps to regulate and deploy BVLOS and autonomous flights	2.4 Design standards for remote ID drone tracking	3.4 Facilitate UAS communities	4.4 Enhance funding opportunities for UAS research	5.4 Provide funding capacity to develop innovative start-ups
1.5 Enhance regulations to meet current and future requirements of airspace users	2.5 Design and implement a phased approach to deploy advanced UTM systems	3.5 Enhance access to UAS technology	4.5 Facilitate international exchange programs	5.5 Identify regulatory opportunities for stimulating UAS demand

Source: PwC 2022a.

1 Regulations and Processes

1.1 Enable a robust UAS ecosystem governance structure and coordination between governmental bodies

Set up a clear division of the roles, tasks, responsibility, and accountability between public institutions regarding the UAS ecosystem. Single tasks should be exclusive to one entity. If not, propose clear procedures to reach such an alignment. Governance should include a holistic view of all related aspects.

Impact: ○ ● ○
Complexity: ○ ● ○
Cost: ● ○ ○
Duration: Short
Recurring: ⊗

1.2 Design and establish clear and transparent processes

Communicate with the public about the roadmaps for all processes such as importing, purchasing, registration, certification, licensing, and flight authorization. These should be clearly established and transparent for all ecosystem players. Defining the processes is the first step towards digitalization.

Impact: ○ ○ ●
Complexity: ○ ● ○
Cost: ○ ● ○
Duration: Medium
Recurring: ✓

1.3 Develop the institutional capacities of public bodies

Expend effort to enhance the understanding and awareness of the drone market among relevant public institution bodies. Increase human resources in public institutions to meet the constantly-growing demand for drone services. Developing processes and digitizing these functions will provide acceptable service levels for core UAS operations and activities.

Impact: ○ ○ ●
Complexity: ● ○ ○
Cost: ○ ● ○
Duration: Long
Recurring: ⊗

1.4 Create roadmaps to regulate and deploy BVLOS and autonomous flights

Enable safe BVLOS operations with a mechanism for waivers, especially during emergency and medical applications. Prepare for a phased transition from such individual waivers to automated BVLOS flight approval processes. The end goal is to ensure that this is done within a UTM system that includes live tracking and full airspace separation. A key element is public awareness, acceptance, and support of such innovative applications.

Impact: ○ ○ ●
Complexity: ○ ● ○
Cost: ○ ● ○
Duration: Long
Recurring: ⊗

1.5 Enhance regulations to meet current and future requirements of airspace users

Update regulations regularly to reflect advances in drone technology, particularly around transportation use cases, BVLOS, flying over people, night flights, UTM, and autonomous operations. Ecosystem players should collaborate with regulators to define a vision of the new ecosystem and set clear goals for each step of implementation.

Impact: ○ ○ ●
Complexity: ○ ○ ●
Cost: ○ ● ○
Duration: Long
Recurring: ✓

● Low ● Medium ● High

2 Digitalization and Automation

2.1 Utilize and integrate systems of key UAS ecosystem stakeholders

Establish effective communication protocols with public authorities (such as CAA, ANSP, and relevant ministries, departments, and institutions). This should allow fast and secure digital workflows for decision-making related to UAS requests such as drone registrations, flight approvals, and the like. Ideally, ll stakeholders should have access to a single communication/decision-making system.

Impact:	○ ○ ●
Complexity:	○ ● ○
Cost:	○ ○ ●
Duration:	Medium
Recurring:	⊗

2.2 Digitalize basic services

Automate functions and processes such as drone registrations and pilot certifications using digital platforms that require minimal technical effort. Create clear, intuitive walk-through guides for users within an easy-to-use and secure digital environment.

Impact:	○ ○ ●
Complexity:	○ ● ○
Cost:	○ ● ○
Duration:	Medium
Recurring:	⊗

2.3 Digitalize advanced services

Create web portals and mobile applications that give access to digitized maps of airspace zones. Integrate with other data sources such as NOTAMs and temporary restrictions, and update in real-time. This should be followed by automated risk assessments and flight authorization workflows. A clear path for restricted flights should also be made available for pilots.

Impact:	○ ○ ●
Complexity:	○ ○ ●
Cost:	○ ○ ●
Duration:	Long
Recurring:	⊗

2.4 Design standards for remote ID drone tracking

Enforce clear standards for remote ID that enables complex, autonomous, and BVLOS drone use cases. This requires adding broadcasting hardware to selected classes of drones; establishing design and production rules for manufacturers; including operating rules for pilots; and other key regulations.

Impact:	○ ○ ●
Complexity:	○ ○ ●
Cost:	○ ○ ●
Duration:	Long
Recurring:	⊗

2.5 Design and implement a phased approach to deploy advanced UTM systems

Introduce the concept of a UTM system that is appropriate for the local environment. Define and create an entity that is responsible for its implementation. The following phases include the creation of a piloting roadmap; introduction of scope of services; provision of a framework for public consultation; and implementation of the UTM system, complete with supervision and execution.

Impact:	○ ○ ●
Complexity:	○ ○ ●
Cost:	○ ○ ●
Duration:	Long
Recurring:	⊗

● **Low** ● **Medium** ● **High**

3 Awareness and Promotion

3.1 Increase awareness among the community

Organize public initiatives and programs to drive awareness about drone technology, use cases, pilot projects and future possibilities. This is critical to increase trust, and allow relevant authorities and stakeholders take informed decisions when it comes to enabling the drone ecosystem.

Impact:	○ ○ 🔴
Complexity:	🟡 ○ ○
Cost:	🟡 ○ ○
Duration:	Long
Recurring:	✓

3.2 Develop UAS-related publications

Create and publish reports, articles, videos, and other material to create positive associations with drone technology. These should be based on local specificity while introducing proven beneficial use cases from around the world. This includes the promotion of local and regional companies and organizations developing drone technologies and distributing reports to important stakeholders and media.

Impact:	🟡 ○ ○
Complexity:	🟡 ○ ○
Cost:	🟡 ○ ○
Duration:	Medium
Recurring:	✓

3.3 Organize events for key stakeholders

Gather exhibitors, panelists, and participants from regional and global companies and institutions at UAS-related conferences, summits, or hackathons to enhance knowledge exchange. These events could be used to kickstart initiatives that activate demand for UAS services, while engaging relevant stakeholders.

Impact:	🟡 ○ ○
Complexity:	🟡 ○ ○
Cost:	○ 🟠 ○
Duration:	Short
Recurring:	✓

3.4 Facilitate UAS communities

Establish communities, associations, and forums in an organic manner to involve all ecosystem stakeholders. Their role and mandate must be carefully defined. Many existing communities are under the aegis of the CAA, but this can differ based on local context.

Impact:	○ 🟠 ○
Complexity:	○ 🟠 ○
Cost:	○ 🟠 ○
Duration:	Long
Recurring:	⊗

3.5 Enhance access to UAS technology

Enable and support access to best-in-class UAS technology for drone service providers, manufacturers, and software developers. In some regions, the availability of UAS technology is limited by strict regulations which slows progress. Additionally, taxes and tariffs are other mechanisms that create a significant barrier to importing UAS hardware, spare parts, and other components.

Impact:	🟡 ○ ○
Complexity:	○ ○ 🔴
Cost:	○ ○ 🔴
Duration:	Long
Recurring:	⊗

🟡 **Low** 🟠 **Medium** 🔴 **High**

4 Knowledge and Education

4.1 Offer easy access to UAS-related information

Provide information about regulations and safety in an easy-to-understand way to ensure higher community engagement, better compliance to regulations, and a reduced risk misbehavious. A dedicated website and mobile app should be created that provides easy access to clear information regarding UAS safety, regulations and processes, include air maps with fly/on-fly zones, and facilities access to information about where to apply for special permissions.

Impact:	○ ● ○ (Medium)
Complexity:	● ○ ○ (Low)
Cost:	● ○ ○ (Low)
Duration:	Medium
Recurring:	⊗

4.2 Create and certify UAS training centres

Enable wide access to UAS training for the general public under the CAA or external training centres. Establish clear UAS pilot licensing procedures and examination rules. The examination can be provided by the CAA, or it can be decentralised and delegated to external training centres. Create minimum curriculum requirements for the UAS training as well as UAS instructors.

Impact:	○ ● ○ (Medium)
Complexity:	○ ● ○ (Medium)
Cost:	○ ● ○ (Medium)
Duration:	Short
Recurring:	✓

4.3 Design curriculums to support UAS-related education

Update curriculums of courses related to computer vision, geomatics, and remote sensing by integrating modules related to UAS and UAS data. Establish specialized courses and degrees focusing on hardware design, software development, photogrammetry, data analytics, and more, which are relevant to the drone industry. Facilitate the creation of research centres or joint initiatives with industry to run research on UAS. The development of UAS technologies and advanced data analytics requires a modem educational curriculum that meets the market needs.

Impact:	○ ● ○ (Medium)
Complexity:	○ ○ ● (High)
Cost:	○ ● ○ (Medium)
Duration:	Short
Recurring:	✓

4.4 Enhance funding opportunities for UAS research

Provide funding opportunities such as grants, subsidies, and scholarship for researchers and innovators to conduct research and development activities. Facilitate cooperation between the industry and research institutions to focus on solving relevant problems and challenges. Facilitate knowledge exchange and results publication, as well as intellectual property protection instruments such as patents. Scientific R7D activities require funding opportunities to operate and to attract the most talented researchers.

Impact:	○ ● ○ (Medium)
Complexity:	○ ● ○ (Medium)
Cost:	○ ○ ● (High)
Duration:	Medium
Recurring:	✓

4.5 Facilitate international exchange programs

Support fellowship programs and secondments between universities and public institutions within each region. Periodic meetings of public agencies and research institutions from different parts of the region should be organized with a focus on knowledge sharing of best practices and the creation of upskilling opportunities. Collaboration between government private industry, facilitating the exchange of best practices in a transparent and effective way, should be prioritized.

Impact:	● ○ ○ (Low)
Complexity:	○ ● ○ (Medium)
Cost:	○ ● ○ (Medium)
Duration:	Medium
Recurring:	✓

● **Low** ● **Medium** ● **High**

5 Demand and Entrepreneurship

5.1 Organize business forums to match demand with supply

Facilitate the creation of working groups, business forums, or other opportunities where public sector organizations, government agencies, and UAS companies can exchange knowledge about their work, best practices, and challenges. Identify digitalization needs in the public sector companies and corresponding drone use cases that could effectively solve those critical challenges. Establishing such collaboration and interaction opportunities leads to knowledge exchange, accelerated technology adoption and stimulating the demand for UAS services.

Impact: Medium
Complexity: Low
Cost: Low
Duration: Short
Recurring: ✓

5.2 Provide funding to test and pilot UAS technologies

Accelerate adoption of disruptive technologies and make it easier for UAS companies to propose pilot projects to the public and private enterprises with a well-structured technology piloting program. The outcomes and lessons learnt from such projects should be publicly available to enable a bigger impact on the UAS sector as a whole.

Impact: High
Complexity: Low
Cost: High
Duration: Short
Recurring: ✓

5.3 Enable incubators and accelerators

Engage public and/or private entities in establishing accelerators and incubators. Establish specialized paths for startups developing UAS-related technologies. Build a mentorship culture to coach and lead new entrepreneurs. Create space for prototyping, test flights, and experimentation. This is an essential stimulus for young entrepreneurs who are developing drone start-ups.

Impact: Medium
Complexity: High
Cost: High
Duration: Long
Recurring: ⊗

5.4 Provide funding capacity to develop innovative start-ups

Create public (e.g., government programs) and private funding (e.g., venture capital) for start-ups to help in both the initial stage as well as in scaling their business operations. The funding rounds sizes should reflect the needs and requirements of startups and be competitive with global standards. Securing funding is critical for industry development, and for the creation and scaling of new technologies.

Impact: High
Complexity: Medium
Cost: High
Duration: Medium
Recurring: ✓

5.5 Identify regulatory opportunities for stimulating UAS demand

Identify how regulatory requirements or recommendations related to the digitalization of various industries could indirectly stimulate the demand for UAS services. For example, cyclical provision of drone technical products for public capital projects can enable better control over construction sites. Recommend that utility companies work towards digitizing their documentation, including the image data of difficult to reach places such as dams. This approach can improve the transparency and awareness of public projects.

Impact: Low
Complexity: Medium
Cost: Medium
Duration: Medium
Recurring: ✓

● Low ● Medium ● High

The importance and characteristics of each initiative can be categorized according to the resources required for implementation, the complexity of the implementation, and the potential impact of each initiative. Doing so can assist with effective prioritization as LAC countries build their own unique drone ecosystem development roadmap.

The higher the impact and complexity, the more resources are required (Figure A5.2). Complex initiatives also need more time to be prepared and deployed, so these initiatives should be addressed earlier. This is not to say that resource constraints should be overlooked during development. There are a range of important initiatives that can be implemented inexpensively and in a relatively simple manner. These *starter initiatives* can generate positive momentum and move a drone ecosystem in the right direction.

Figure A5.2. Strategic Drone Development Incentives for LAC Countries

Source: PwC 2022a.

Appendix 6. Methodology and Content of the Analytical Work

Overview of the Engagement and General Methodological Approach

The World Bank, in collaboration with the Global Infrastructure Facility, conducted a comprehensive study analyzing the status of drone adoption and implementation across LAC. Spanning the years 2021–23, the study encompassed three distinct phases, resulting in the production of seven detailed reports and topic snapshots. Following a mixed-methods approach, the study integrated desk research sourced from both international and national repositories. This included examining statistics, country overviews, academic papers, and research publications related to drone pilots and national UAS regulatory frameworks in the region. Additionally, the study benefited from insights and experiences of over 45 in-depth interviews with key stakeholders from the local and international drone ecosystem, as well as representatives from civil aviation authorities (CAA). Workshops and working sessions with various stakeholders further enriched the qualitative insights gleaned from the study.

The study's methodology and approach supported the identification and mapping of over 650 native drone ecosystem players, alongside the presence of international counterparts. Through meticulous examination of publicly available regulatory information and interactions with CAAs, the study provided a comprehensive review of drone regulations across participating countries and sub-regions. Moreover, it identified 12 pertinent use cases aligned with the 2030 agenda and the developmental aspirations of the countries under study.

A critical aspect of the study involved conducting a thorough market analysis and forecasting UAS commercial services within the region. These insights, coupled with the identification of initiatives reflecting the state of technological adoption, regulations, and the UAS ecosystems itself, aimed to stimulate the advancement of the UAS agenda across LAC. By uncovering key market trends and outlining strategic pathways for future development, the study aimed to unlock the full potential of drone technology in addressing regional challenges and fostering sustainable growth.

Detailed Description of the Three Phases of the Study for LAC

The first phase entailed assessing drone ecosystems in the region, identifying key use cases and native market players, and determining the varying states of regulatory framework across the LAC region. It also involved analyzing global regulatory and UTM trends, along with international UAS ecosystem benchmarks from five countries: United States, Switzerland, Poland, Spain, and Rwanda. A detailed examination of the five selected LAC countries was also involved. Furthermore, this phase encompassed a market analysis that projected the current and forecasted market potential for drone services across different industries per country, estimating the job creation potential of the UAS commercial service industry, and forecasting the number of commercial and recreational drones until 2026.

The second phase focused on exploring use cases for drone technology in development activities in the LAC region. It examined 14 areas of potential application to assess the relevance and level of development in a regional context. Additionally, this phase addressed business models for drone operations, identifying key initiatives necessary for expanding and consolidating the drone ecosystem over the next five years.

The third phase involved a deep dive into Guatemala, Brazil (specifically Tocantins State), and Haiti, which served as prominent case studies in the LAC region. Country reports and snapshots were developed for Phases I and II.

Detailed Methodological Approach for Each Analysis Performed during the Study

To complete the analytical work on "Latin America and Caribbean: Support for Remotely Piloted Aircraft Systems (Drones)", various methodological approaches were employed to generate accurate insights about selected topics across the three phases. Detailed descriptions for each topic are provided below to offer a comprehensive overview of the approaches used for the: Drone Ecosystem Assessment; Drone Regulatory Framework Assessment; Assessment of the Market Potential of Drone Services; Strategic Development Initiatives for different levels of development of Drone Ecosystems in LAC.

Drone Ecosystem Assessment

Drone ecosystem assessment is a key part of the benchmarking analysis used to identify best practices across the world, and more specifically, the LAC region. For this exercise, vital drone landscape elements and components were identified and analyzed to determine the stage of development in each of the countries studied. This approach allowed for an ecosystem study conducted from different dimensions, thus enabling the identification of strengths and weaknesses, development opportunities, and key recommendations. The list of all the components analyzed, their explanation, and development scale ranking is presented on Figure A6.1.

Figure A6.1. UAS Ecosystem Components

	Component	Maturity			Comment
Supply & Demand	Industry Readiness	Early adopters	Selected companies	Wide adoption	Readiness and willingness of the industry players to purchase UAS-realted services.
Supply & Demand	Access to UAS Operators	Mainly hobbyists	Limited	Wide professionals	Number of UAS operators providing required services on the market, their level of skills and professionalisation of the services.
Supply & Demand	Training & Education	Not available	Available	Widely available	Availability and number of schools offering courses for UAS operators.
Supply & Demand	Insurance	Not available	General	Dedicated	Availability of insurance providers, type of available policies (adjustment to specific requirements) and presence of UAS specific policies.
Supply & Demand	Marketplace & Other	Not available	Basic	Advanced	Availability of additional services, such as marketplaces for UAS services, repair and maintenance services providers ensuring sale and smooth functioning of the hardware etc.
Regulation	Execution of Regulations	Low	Medium	High	Effectiveness of regulations measured by compliance to it easiness to comply.
Regulation	Approach to BVLOS	Not available	Waivers	Allowed	Possibility to fly Beyond Visual Line of Sight (BVLOS).
Regulation	Licensing & Examination	Not available	Operated by CAA	Certified centers	Existence and organization of processes to license and examine UAS operators.
Digital readiness	Registration & Identification	Not available	Analog	Digital	Requirement to register UAS and availability of comprehensive UAS identification system.
Digital readiness	Fight Authorization Time	2+ weeks	1-2 days	Instant	Time needed to get an approval to fly am IAS in controlled airspace.
Digital readiness	Airspace Maps	No access	Descriptive	Digitalized	Availability, type, level of advancement and access to airspace maps that contribute to easiness of the use of UAS technology.
Digital readiness	Identification & Tracking	Not available	Digital fight plan	Remote ID	Presence and/or advancement of the technology to provide UAS operations tracking, drone identification and verification of flight plans.

Source: World Bank.

In this analysis, three vital components for the drone ecosystem were included: supply and demand, regulation, and digital readiness.

To analyze the supply and demand dynamics, the industry player's ability to buy drone services was assessed, as was the provider's readiness to offer them. The experience of auxiliary service providers, including drone hardware and software resellers, training and education centers, hardware repair companies, and drone insurers was also taken into consideration.

For the regulation component, an overview of the key elements of the regulatory framework that focused on a drone operator's journey—purchasing the hardware to planning a mission, and executing the flight to collect data—was developed.

As part of the digital readiness analysis, the digital tools facilitating the drone ecosystem were identified and availability of these tools in the region was assessed.

Drone Regulatory Framework Assessment

Extensive research was conducted on the drone regulatory frameworks of selected countries in the LAC region. The goal, to gain insights into the mandates of civil aviation authorities (CAAs) and to understand the unique UAS rules that constitute each country's regulatory framework. To achieve this:

- Each country's regulations were evaluated in a descriptive manner. That involved analyzing available legislation documents or conducting consultations with key local actors engaged in the drone's ecosystem, particularly from the business or regulatory sectors.

- A comprehensive scoring system was developed, based on regulatory elements deemed crucial for market development.

- A statistical analysis with clear rating rules-ranging from "no regulations" to "advanced"–was established and conducted to determine the advancement level of each country's regulatory framework.

- The regulatory rating that offered additional insights into the region's characteristics and spatial distribution of regulatory frameworks was then presented on a map.

In order to provide a relevant scoring system, key regulatory elements were selected to be analyzed (Figure A6.2).

Figure A6.2. The List of Key Selected Drone Regulatory Elements That Are Covered in the Analysis

Drone regulations elements which are covered in the analysis	
Drone regulations in place officially	Flight Management processes established
Drone regulation adoption year	Permitted drone flight altitudes
Drones prohibition	BVLOS (Beyond Visual Line of Sight) flights
Drone registration	Insurance requirements
Pilots training and certification	Flying over crowds

Source: World Bank.

Based on predetermined criteria, an index was developed to assess the stage of drone regulation development in the selected countries. The key principles guiding this process included a thorough understanding of the existing regulatory frameworks and research that formed the basis for an expert-driven approach. This method used a point scoring system with weighted categories.

While all categories and dimensions were considered, particular emphasis was placed on categories essential to the drone ecosystem. These included official drone regulations, unmanned traffic management initiatives, drone registration, and insurance. These elements were identified as crucial for fostering a safe and sustainable ecosystem, drawing insights from global trends and successful benchmark countries.

To provide additional context, statistical breakdowns of ratings and color-coded maps illustrating individual countries' ratings in the region were presented. The goal of the presentation was to offer a clearer perspective on the results and to facilitate comparative analysis.

As the final step, country ratings were categorized into four stages: no regulations, early stage, intermediate, and advanced. This classification framework aimed to provide a standardized approach for assessing and categorizing the regulatory landscape across the region, enabling stakeholders to assess progress and identify areas for improvement.

Assessment of the Market Potential of Drone Services

The market assessment of drone services in the LAC region is based on a detailed analysis conducted for 35 selected LAC countries. The market model was prepared during 2021 and data sources for the previous years were used to assess the market size and to showcase the potential of drone services up to 2026.

The methodology of the analysis used in the report comprises two estimation approaches: bottom-up and top-down (Figure A6.3). These were used to define the total market potential representing the value that the total market could reach if all current works were performed by UAS; and the total market size representing the current size of the market, considering the current adoption of UAS technology (Figure A6.4).

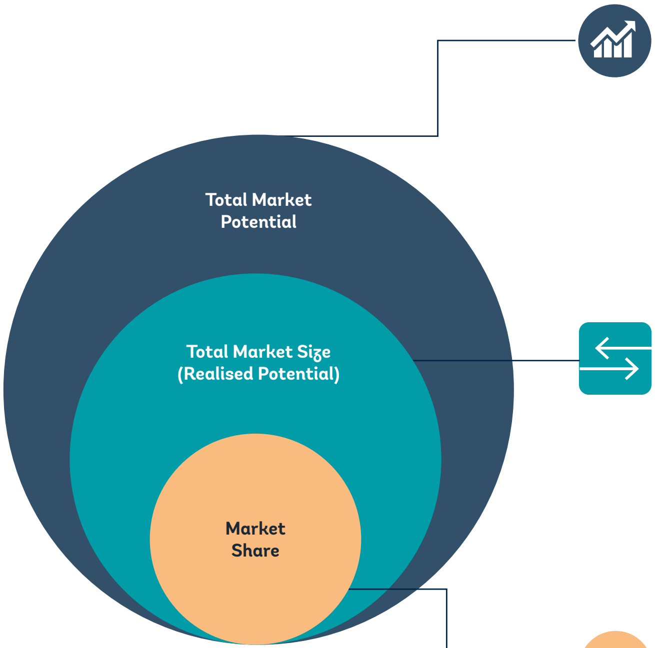
The transition from market potential to market size is achieved by considering a technology adoption rate represented by applicability. Current drone initiatives, the development of services, and international benchmarks were all considered to estimate the relevance of different use cases in the LAC region.

Figure A6.3. Estimation Approached Used for the Analysis

Estimation Approach
Bottom-up • Estimation of the market on the basis of identified drivers (market segments) that contribution to the final market value (entire market). • Final market value was calculated as the volume of infrastructure, data etc. multiplied by the price of the services to be performed in relation to the infrastructure. • A comprehensive approach was used for a detailed calculation of the market potential.
Top-down • Estimation of the value based on reliable data for entire market and factors for extrapolation. • Simplified approach used for high-level estimations.

Source: World Bank.

Figure A6.4. Components of the Market Assessment



Total Market Potential

- Represents the value if all current work done by traditional methods is replaced by drones.
- Growth of the market potential is dependent on growth of the infrastructure (e.g. growth in pipelines length or infrastructure development)

Total Market Size

- Represents the current forecasted use of UAS technology
- Growth is dependent on infrastructure (similarly as total market potential), but it also depends on adoption of UAS technology which is what makes it more dynamic.

Market Share*

- Represents the value of the market that can be captured by a specific company or entity taking into account also other players operating on the market.

*Market share was not a subject of analysis for this project

Source: World Bank.

In order to understand which sectors have the biggest impact on the economy in each of the 35 LAC countries, 30 UAS use cases adopted globally that are the most relevant to the local market were considered.

Despite the robust quality of the model, several key limitations should be considered. These include the reliability and availability of data across LAC countries, their industrial sectors, the unpredictable pace of technological progression and policy changes, potential fluctuations in global and local economic conditions, assumptions related to the 30 UAS use cases, unforeseen geopolitical events, and various environmental factors. All these elements have the potential to significantly impact the accuracy of the projected market potential and size in the analysis.

To showcase the rapid pace of drone technology adoption and the demand for its services, a forecast to 2026 of various types of commercial UAS—multirotor, fixed-wing, VTOL, and tethered drones—was created. Following the launch of the commercial market and the institution of all necessary processes, the development of the recreational UAS market is expected to increase. The number of recreational drones forecast until 2026 stands as a part of the conducted analysis.

The analysis also showcases the direct and indirect job creation potential of the UAS commercial service industry up to 2026. As part of the applied methodology, the number of direct jobs created was calculated using a bottom-up approach with consideration given to both in-house and outsourced models of UAS delivery services. The number of indirect jobs created was estimated with a top-down approach based on a current assessment of international workforce benchmarks; a bottom-up approach was estimated where data were available. The list of selected direct and indirect job categories is specified on Figures A6.5 and A6.6.

Figure A6.5. Detailed Specifications of Categories That Came as a Part of Direct Jobs

Direct Jobs	
Defined Category	**Specifications**
Drone Operators	Execution of drone operations for all use cases and sectors
Data Processing Specialists	Processing geospatial data and creating engineering products from the footage gathered by drones
Analysts	Perform detailed analysis of the products after processing and preparation of analytical reports
Machine Learning Specialists	Development and implementation of machine learning algorithms
Management	Supervision activities

Source: World Bank.

Figure A6.6. Detailed Specifications of Categories that Came as a Part of Indirect Jobs

Indirect Jobs	
Defined Category	**Specifications**
Enablement Services	Jobs that include the following: airspace traffic management, regulatory bodies, training facilities, insurance providers
Product Sales	People who sell hardware in specialised stores (which constitute only part of total sales)
R&D	Specialists in research centres related to work on the development of new global and local technologies
Beneficiaries	People at major companies that will purchase UAS services from the market in the outsourced model and manage completion of the projects
Hardware and Software Development	Engineering positions in local companies that are manufacturing drone-related hardware and software
Support Staff (back-office)	Jobs in UAS-focused companies in departments such as marketing, finance, HR and procurement
Other	All other jobs created by the sector in industries such as media (journalism and blogs), events and UAS competitions (both sport and e.g. hackathons), and the wider marketplace.

Source: World Bank.

Strategic Development Initiatives for Different Levels of Development of Drone Ecosystems in the LAC Region

To ensure the expansion and advancement of the drone ecosystem in each country of the LAC region, strategic drone development initiatives were created because of an in-depth analysis of global best practices and local requirements. The applied methodology consisted of five phases, with a primary objective of identify strategic initiatives that could encompass both foundational and more complex initiatives and programs. These initiatives aimed to support the development of countries across the region with early-stage and intermediate level ecosystems. The following activities were executed as a part of the phased methodology (Figure A6.7).

The proposed drone ecosystem framework defined eleven elements divided into three categories: foundational, enabling, and overarching. These elements summarize all the important aspects of the long-term vision for a competitive drone sector and are relevant to achieving the maximum growth in the UAS sector.

Global and the LAC region best practices were analyzed based on drone-related initiatives and programs that impact the ecosystem. The analysis of global best practices showed that elements of the drone ecosystem framework are often developed simultaneously as part of a larger drone strategy and followed by interconnected initiatives. The initiatives have been summarized into five main pillars.

A deep analysis of the drone market in conjunction with over 45 interviews with stakeholders were conducted to understand and define the LAC region specific needs and requirements. Based on the input, a list of 25 strategic drone development initiatives required to develop the drone ecosystem in a long-term and sustainable way for LAC was created. According to defined initiatives, two illustrative ecosystem development roadmaps of countries across the region were created, one for early and intermediate stage development and the other for advanced stage development.

Figure A6.7. Implemented Phased Approach Towards Achieving Strategic Drone Development Initiatives

1 Drone Ecosystem Framework

Governance			Overarching
Entrepreneurship	Technology	Training & Education	Enabling
Funding & Financing	Awareness	Research & Development	Enabling
Regulations	**Processes**		Foundational
Operations	**Sustainability**		Foundational

2 Global Best Practices

3 Drone Ecosystem Development Pillars

Regulations and Processes	**Digitization and Automation**	**Awareness and Promotion**	**Knowledge and Education**	**Demand and Entrepreneurship**
Clear regulatory framework to ensure safety while stimulating innovation and enabling future use cases	Digitalization of processes to facilitate ease of providing services for SMEs and scaling capacity of public institutions	Building trust and awareness among public stakeholders, society and industry to facilitate the adoption of innovative and relevant UAS solutions	Growing human capital by providing access to high quality education to stimulate scaling and rendering of innovation	Stimulating innovation by providing entrepreneurs with the means to accelerate their market entry and scaling the development of the technology
Transparent processes and procedures to facilitate straightforward compliance with regulations and related processes	Introduction of digital unmanned traffic management services to control and safely integrate UAS into the airspace	Fostering innovation by connecting startups, industry and research	Facilitating sustainable airspace safety by educating users and stakeholders about regulations, best practices and responsible behaviours	Stimulating demand for drone products and services by providing instruments to activate the market

4 The LAC Region Needs and Requirements

5 Strategic Drone Development Initiatives for LAC region and Roadmaps for Early and Intermediate/Advances Stage Drone Ecosystem

Source: World Bank.

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