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Giving wings to a drone-powered India:

Mapping enablers and opportunities

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Abstract

Commercial usage of drones is gaining momentum the world over. From aiding aerial photography for journalism, film or at weddings to delivering vaccines and medicines to remote corners of a country, drones have a host of applications. Unsurprisingly, investments in drone technologies are soaring as research estimates galloping growth for drones in the coming decade. Governments in India and elsewhere, for their part, are welcoming these initiatives and hoping to unlock the full potential of drones in driving economic growth. Due to the nascent stage of this sector, the time is ripe for concerted efforts among the government, industry, and civil society to resolve uncertainties on safety, security, privacy, and other regulatory and governance issues. Such building blocks are fundamental to ushering in a future of urban mobility powered by drones. As is expected, every nation has factors that are unique to it that enable the accelerated adoption of new technology. In this context and in the backdrop of the positive outlook India's witnessing on the potential of and demand for drones, this white paper outlines the enablers that could help build a thriving ecosystem for drones, suited for India, with learnings for the world.

Introduction

The second half of the 20th century was marked by the internet-enabled access to information reshaping conventional ways of life and creating a new world order. Harnessing the power of all things digital, the 21st century is revolutionising how we move, work, and live, enabled by the new paradigms of mobility: shared, connected, electric, AI-powered, and autonomous (McKinsey & Company, 2020). The new paradigms of mobility are gaining currency in policy quarters spurring innovation and investment, improving efficiencies of our cities, and enhancing the quality of life (Singhal et al., 2018). The Urban Air Mobility (UAM) ecosystem is a concept that visualises this transformation. As the world beckons to the Fourth Industrial Revolution, Drones or Unmanned Aerial Vehicles (UAVs), a subset of the UAM ecosystem, are proliferating the civilian airspace indicating the impending revolution that lies ahead.

UAV operations are more than a century old. Since the 1800s, armies around the world have been using drones for training, bombing, surveillance purposes. Interestingly, as warfare paved the way for the revolution of drone technologies into civilian space, it was only in 2006, after close to 150 years of military use of drones, that a commercial drone permit was granted (Vyas, 2020). Today drones have a myriad of commercial use cases and continue to expand across sectors. The vast and varied potential has been a catalyst to its exponential growth in the last few years.

The growth is best illustrated by the global commercial drone market, valued at USD 9.5 billion in 2020 and estimated to grow to USD 92 billion by 2030 (Onag, 2020). Drone manufacturers and their allied sector actors are thus constantly engaged in designing, testing, and improving solutions for various market applications. In the wake of the COVID-19 outbreak, there has been a considerable increase in the utilisation of UAVs, with drones assisting with transportation of medical supplies including vaccines, and monitoring and guidance during lockdown and quarantine (UNICEF, 2020). Supporting the decisions taken by many governments, multilateral organisations like the UNICEF have been spearheading the introduction of drones "to reach the poorest, hardest-to-reach communities" (UNICEF, 2021). Going into the future, transportation will be one of the top three promising sectors for drone use (PwC & Faraz, 2018).

In India, drones are integrated in the civilian sector in many ways (Swaminathan, 2015): (a) in *agriculture*, for spraying fertilisers, monitoring soil quality, erosion, and maturity of crops, etc.; (b) in *forestry and wildlife conservation*, for tiger census and tracking wildlife; (c) in *mapping and monitoring*, for ecological audit, soil quality testing, town planning and

logistics, rescue and relief work, for disaster management including multi-stakeholder efforts against the Covid-19 pandemic, and even keeping an eye out for poachers; (d) in *earth sciences*, for measuring geophysical processes associated with natural hazards like earthquakes and volcanoes; (e) in *law and order*, for monitoring large public gatherings, border surveillance, coastal and maritime security, oil and natural gas pipeline monitoring, securing offshore assets like ports, and urban security, and (f) in *media, journalism, and entertainment*, for covering election rallies, film-making, and even wedding photography. With their use thus enmeshed in the civilian sector, drones are here to stay, indeed. In the last decade or so, films like *3 Idiots*, *Uri: The Surgical Strike*, and *Sherni*, among others have captured the popular imagination on drone applications, paving the way for widespread acceptance of the same among the masses.

Drones are a fast-growing industry today. Studies estimate that the drone market is expected to reach USD 1.21 billion in 2021 (Krishnankutty, 2021). As investments into the sector grow along with a favourable regulatory climate, drone usage is set to shift gears in the coming years. A major thrust will be provided by the willingness of the government to use drones for a variety of applications, pushing the projected value of the domestic industry further north (FICCI & EY, 2018).

Focus of the study

This growth potential of drones ushers in new areas of application cutting across sectors within the Indian context. As use cases expand, investment needs to match the growing demand for drone technology, and this push needs to come from both the government as well as the private sector. The rapid progress of drone technology and applications necessitates an urgent understanding of the regulatory, policy, and technological domains of drone usage, and their implications for India in the current landscape. For drones to become truly valuable and impactful, the legislative frameworks, technology adapted, operational processes, and opportunities assessment need to be well established. In this background, the white paper explores the impact of drones extending to a wide range of sectors, outlines challenges and opportunities for the adoption of drone technology, and maps the use cases for safe, cost-effective, and efficient drone operations in both the global and Indian contexts.

Classification of Drones

Drones are colloquially used as an umbrella term for airborne vehicles without a pilot on board. However, there are specific technical terms that are used to describe drones across countries. The more commonly used terms are Remotely-Piloted Aircraft Systems (RPAS) and Unmanned Aircraft Systems (UAS) (Hassanalian & Abdelkefi, 2017). While there are several categorisation methods, the most common classification is based on the drone's performance characteristics - weight, wingspan, payload capacity, flight range etc. Further based on the propulsion systems, drones are classified as rotor, fixed, and hybrid (Hassanalian & Abdelkefi, 2017). With vertical take-off and landing (VTOL) capabilities becoming integral to drones, categorisations are also based on such systems. The heterogeneity in classification of drones is driven by its myriad applications. As the global market expands, newer and advanced versions are constantly entering the market increasing the different types of models. Drones now come in all shapes and sizes depending on the function they intend to serve (Hassanalian & Abdelkefi, 2017).

Table 1 : Classification based on type				
Parameters/Type	Multi-rotor	Single rotor	Fixed wing	Hybrid
VTOL	Yes	Yes	No	Yes
Max. Payload (kg)	~ 10 kg	~ 15 kg	~20 kg	~30 kg
Speed	~ 65 kmph	~80 kmph	~120 kmph	~120 kmph
Range	5 km	~5-10 km	~15-20 km	~15-20 km
Fuel	Electric	Electric/ fuel	Electric/ fuel	Electric/ fuel

Source: Based on Vergouw et al., 2016; Hassanalian & Abdelkefi, 2017; Khan, 2021; Haller, 2021

The different classifications of drones help differentiate existing systems based on their operational characteristics and their capabilities. Several of these categorisations are also of regulatory importance since they help classify them to chalk out laws. The most common categorisation from a regulatory perspective is based on the weight of drones (Dalamagkidis, 2015).

Table 2 : Classification based on weight			
Class of drones	Type	Weight	Height
Nano	Multi-rotor Single rotor	Less than or equal to 250 gram	Upto 60 meters
Micro	Multi-rotor Single rotor	Greater than 250 gram and less than or equal to 2 kilograms	Flown up to 60 meters Above Ground Level (AGL)
Small	Multi-rotor Single rotor	Greater than 2 kilograms and less than or equal to 25 kilograms	Flown up to 120 meters Above Ground Level (AGL)
Medium	Multi-rotor Single-rotor Fixed wing	Greater than 25 kilograms and less than or equal to 150 kilograms	Upto 120 meters
Large	Multi-rotor Single-rotor Fixed wing	Greater than 150 kilograms	Upto 120 meters

Source: Ministry of Civil Aviation, 2021

As more interesting potential applications are envisioned, drone types and technologies will only get more complex. With drones beginning to attain commercial scalability, it is not beyond imagination to see drone taxis with heavier

payloads transporting humans in India as well (Livemint, 2021), even as pilot projects are rolled out in Dubai (Wakefield, 2017), the US (Hawkins, 2020; BBC, 2021), and South Korea (Bangkok Post, 2021).

What has led to the commercial scaling of drones?

Unsurprisingly, large-scale commercialisation of drones is underway. The shift from military to commercial sector for drones has been rather transformational with significant stages of development. From achieving basic elements of flight reliability to advanced stages of battery components, research and development on various fronts continue to expand drone capabilities (NIAS, 2018). The gradual breakthrough in technology in the last decade has resulted in spurring innovation and development. Numerous factors, as discussed below, have helped achieve commercial scaling of drones.

Development of stable flight capabilities

The turning point that signaled the start of the commercial drone era was to establish stable and reliable flight capabilities. These developments in stability and reliability were the fruits of advancement in drone design, battery, propulsion technology etc. The automation of drones further resulted in its easy operation making them user-friendly, thereby catering to a large pool of users. The aerodynamic and stability efficiency achieved through vertical take-off and landing (VTOL) technology, provide significant advantages to drones. These technologies help accessing areas that are not easily traversable as well as hovering capabilities at low altitude (Bliamis et al., 2021).

Reliable data collection

"Data is the new oil", claimed Clive Humby, a British data scientist, in 2006 (New, 2018). Any development, thus, to refine and aid data collection is much sought after. Drones became valuable in this sense as various stakeholders realise the potential of drones to collect data for various purposes. Hence, once flight stability was achieved this was the point of focus where stakeholders saw a return on investment from drone-related research. The reliability of the drone system ensured the accuracy of the data collected.

Scalability of drone usage

A major challenge of incorporating drones in the commercial space is reaching the desired scale with greater efficiency than existing systems. Drones must not only scale durability and safety, but they should also ensure real-time usage as desired across sectors. The advancement in technology has enabled drones to achieve operation at scale. Applications like mapping and surveillance are widely used in sectors such as mining, construction, traffic management, earth sciences, and more, as listed earlier as well.

Drone integration

Integration of drone systems across sectors has been enabled through a range of factors. Technology has allowed for the scalability of drones to blend seamlessly into the various applications. Rules and regulations, geo-fencing, remote identification, and robust traffic management systems are playing a key role in integrating drones into the mobility ecosystem. Today drones operate in a more holistic environment even as they fly into the future.

Regulations

Despite initial resistance in defining clear regulations for commercial drones, the last decade has witnessed a change in policy and regulatory approach. The laws enabling drone operations, though complex, are currently seeing a liberalised application to unlock the full potential of drones for today and tomorrow. Globally, laws that enable drone operations have in turn led to more innovation in the drone industry.

Evolution of drone technology

A factor equally important, if not more, is the evolution of technology and its role in advancing the purpose of drones. Drone technology is a constantly evolving space, producing a host of new applications. Drone technology covers everything from aerodynamics and materials used in the manufacture of the physical UAV to software, the latter forming the drone's brain. As specified earlier, advancement in technology has further enabled the programing of automated flight paths and enhanced capabilities in terms of payload, greater distance operability and stability in hovering (Vergouw et al., 2016), among others. Undoubtedly, such rapid developments in technology have enabled countries to readily adopt drones and apply them in a variety of contexts.

The following section covers finer aspects of drone technology.

Drone Propulsion Technology

The propulsion system of drone technology helps drones fly and hover. Propellers give drones their forward movement capabilities. The type of a propulsion system is directly linked with tasks that drones are assigned to perform. They are also dependent on the required payload essential for carrying various equipment, speed and endurance. Within the various types of drones the propulsion system works differently. For instance, for fixed-wing drones, the propeller provides forward propulsion, allowing the wing to generate lift. On the other hand for multi-rotor drones, the propellers provide lift as well as steering capabilities by generating downward and lateral forces. The various capabilities of drone propulsion have led to growth in the sector.

Communication and Navigation

Communication and navigation systems allow drones to be operated autonomously or semi-autonomously. Highly accurate system is critical to commercial drone operations. They become even more critical especially in applications such as mapping, surveying, emergency response etc. Further, as drones are expected to perform a large number of tasks going beyond visual line of sight they must be equipped with long-range communication systems. To help provide accurate and reliable navigation systems, commercial drones are enabled with dual Global Navigation Satellite Systems (GNSS) (Patrik et al., 2019). The GNSS system on drones works similarly like GPS navigation units found in cars that helps provide a route map. Advancement in the navigation system additionally helps a drone return home safely when it loses contact with remote control or when battery levels are low. For commercial applications that require holding position, the navigation systems aid drones in increasing stability, as they are able to hold their position with minimal drifting (Patrik et al., 2019).

Sensors

UAVs carry sensors and equipment that form the core of the desired operation. From advanced sensors such as hyperspectral imagers to Light Detection And Ranging (LiDAR), advancements in sensor technology are helping these

unmanned vehicles scale new heights and venture into uncharted territories (Opromolla et al., 2016). Thanks to such sensors, UAVs now have the ability to collect highly accurate data and use the latest software to collate necessary information based on application.

Avoidance and Detection

For a drone to detect objects and then take action to avoid the obstacle involves complex technologies working together to create an integrated system. This entails various sensors and software programming which include mathematical modelling and algorithms. UAV senses and avoids systems that may combine data from a number of sensors. Data is fed back to the drone which can then decide on the best flight path to avoid collision. Sensors, such as radar (radio detection and ranging), ultrasound and LiDAR, emit a signal that can use information to provide accurate distance measurements to obstacles, which are useful for rapid collision detection and prevention (Opromolla et al., 2016).

Battery

The battery powers every onboard component on the drone and is vital for its endurance. The most suitable type of battery is determined by comparing the power density, energy density, weight, volume, cycle life, cost, safety and maintenance of different battery options (Townsend et al., 2020). Each of the criteria affects different aspects of the drone. For example, power density affects the acceleration capabilities, energy density determines the range, the battery cycle life determines how often the battery will need to be replaced, weight and volume affect the range of the system and cost affects availability. While different types of batteries are used to power drones - fuel cell, lithium-ion, nickel-cadmium, and lithium polymer - lithium-ion batteries are most widely used due to their cost-effectiveness and higher energy density, providing more power per unit weight (Townsend et al., 2020). Battery performance is also dependent on the type of drones. For instance, multi-rotor drones use more power and require replacing batteries more frequently. At the same time, today, the fixed-wing segment is projected to lead the drone battery market owing to the high stability and endurance of fixed-wing drones in commercial and civil applications. Battery-powered fixed-wing drones generally use lithium-polymer batteries that have high voltage capacity and enable long-range flight.

Could hydrogen fuel be the future of drone battery technology?

Drones are challenged by limited flight duration and load capacity. While traditional battery power sources are suitable for short-range UAV operations, hydrogen fuel cell-powered UAVs overcome the constraints facing batteries:

- Range: Hydrogen fuel cells give commercial drones 2-4 times the range of batteries. Increased flight endurance boosts productivity, allowing for more to be achieved in a single flight.
- Efficiency: The high energy density of a hydrogen fuel cell makes it more efficient and be used as a lightweight power source for drones. The fast-refuelling capabilities of hydrogen cylinders minimises downtime in operations as well.
- Versatility: Hydrogen cylinders can be sized to fit specific flight times and UAV capacities. Additionally, the fuel cells and cylinders have multiple mounting possibilities which offer greater flexibility.

Beyond Visual Line of Sight (BVLOS)

The terms Visual Line of Sight (VLOS) and Beyond Visual Line of Sight (BVLOS) are used regularly in the drone industry. VLOS operates where a remote pilot maintains continuous, unaided visual contact with the UAV. This allows the remote pilot to control the flight path of the unmanned aircraft in relation to other aircraft, people, and obstacles to avoid collisions. Unaided visual contact refers to natural eyesight; binoculars, telescopes etc. are not permitted for VLOS flights. In the simplest terms, a VLOS aircraft must always be visible to the pilot. BVLOS, on the other hand, is piloted without maintaining visual line of sight on the aircraft at all times. Drones flying beyond visual line of sight are controlled by data provided by on-board instruments. Information is transmitted that informs the operator about the position, altitude, speed, and direction of flight as well as all relevant parameters of the aircraft.

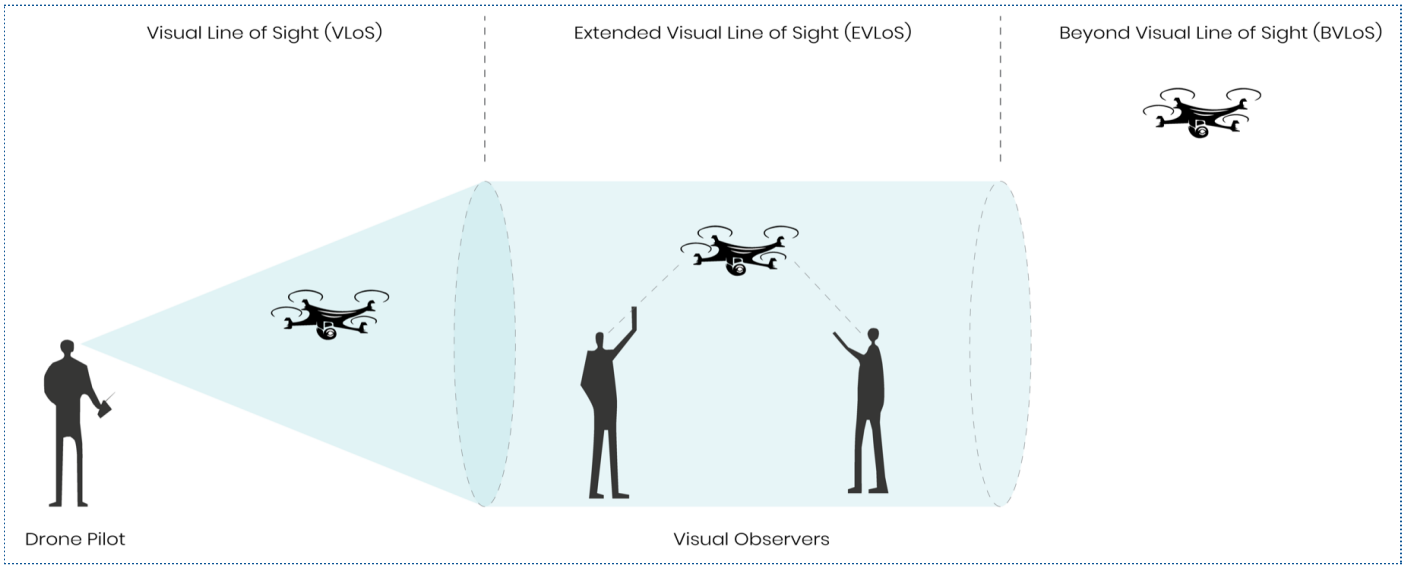

Figure 1: Visual representation of drones operated within visual line of sight and extended visual line of sight, and drones operated beyond visual line of sight. Source: Soarizon (Soarizon, 2020)

BVLOS drone operations provide numerous advantages over regular line-of-sight flying. They are more cost-effective, and efficient. They help replace traditional and more expensive alternatives such as helicopters. BVLOS flights typically require less human intervention as some or all of the mission may be automated. They also allow easier access to remote or hazardous areas. However, BVLOS operations carry significant safety concerns. There is the additional risk of collisions with other aircraft or damage to property and people, especially when flights take place in non-segregated airspace. BVLOS flights are usually subject to permission from aviation authorities. The next big opportunity to unleash the full potential of drones will lie in easing of regulation around BVLOS, while ensuring safety and security of citizens, cities, and countries.

The pace of evolution of drone technologies will enable the embedding of drones in our everyday lives in the near future. Even as advancements in drone technologies take place and those in turn unlock new applications, it will be pertinent to outline the future of drones around the world. A key reason to do so would be to better prepare policymakers and regulators in accepting and leveraging drone technologies. The commercial interest in drones necessitating enhanced autonomy and improved safety will also lead to the rapid creation and adoption of regulatory standards. These and other enhancements have the potential to further impact a wide array of industries, such as commercial transport and logistics, thereby increasing drone applications.

Drone applications in India and the world

Drones are proving their value, gaining a stronghold in a variety of sectors, opening up new opportunities, and generating efficiencies across industries. They have emerged as a versatile tool capable of being applied to a wide range of contexts. For instance, industrial stakeholders are increasingly using drones to improve and optimise industrial processes as well as enhance operational efficiencies. Additionally, drones have started replacing hazardous works such as mining and construction around the world (McKinsey, 2017).

In the last decade, technology has improved significantly, and, as drone sizes reduce, their numbers and capabilities have increased (Singhal et al., 2018). Today, UAVs have emerged as a cost-effective and efficient solution for commercial applications such as surveying, mapping, and aerial photography, among others, and are poised to create impact across sectors. As development beyond the visual line of sight (BVLOS) progresses, it opens a plethora of opportunities for scaling commercial operations for various use cases.

As new regulations take shape in congruence to advancements in technology, they streamline the process of flying drones in the commercial space. Several enterprises and consortiums have identified new business opportunities and are leveraging the use of drones.

Table 3: Select commercial application of drones

Infrastructure inspection and maintenance			
Energy	Mining and Construction	Insurance	Telecom
• Infrastructure surveillance • Pipeline and powerline surveillance	• Construction surveillance • Material Transport	• Roof and site inspection • Impact assessment	• Cell tower inspection • Interim connectivity provision
Environment inspection and maintenance			
Agriculture		Public safety and security	
• Crop, livestock, and land monitoring • Crop spraying		• Police • Disaster mitigation monitoring • Border and highway control	
Transport and Leisure			
Goods Transportation		Leisure	
• Parcel medical supply delivery • Cargo planes, air freight		• Photography • Entertainment	

Source: Swaminathan, 2015; Roland Berger, 2019

The applications listed in *Table 3* are not exhaustive. Drones have several applications, some of which are yet to be explored. With use cases that spread across inspections, monitoring, and data collection, the future of drone technology is also dependent on the development of sensors in many ways. From multispectral camera sensors for agriculture to thermal sensors for search and rescue, drone technology is rapidly changing (Opromolla et al., 2016). Today, new drone-mounted multi-sensor systems harnessing the power of Artificial Intelligence and Machine Learning are being used for critical infrastructure inspections. This wide spectrum is only an indication of the potential or promise of drones going forward. As the UAV market continues to grow, consumer-centric innovation will be one of the most prominent factors in that growth. Passenger drone market will be the future of urban mobility and is likely to be worth US$21 billion by 2035 (Deloitte, 2018).

Case study: Medical supply delivery through drones
Location: Naples, Italy **Partners**: Italian Civil Aviation Authority (ENAC), Monaldi Hospital, Elite Consulting **Project**: Test the potential of drones to deliver medical supplies from the hospital to locations within a 5 km radius. **Equipment**: DJI Matrice 210 V2 (Drone), with a custom-made delivery box that can be adjusted to carry medicine, blood samples or cotton swabs for testing to and fro infected areas. **Finding**: Not only does this solution limit the exposure of medical staff in crises like a pandemic, it also reduces the delivery time from 35 minutes to 3 minutes.
Location: Mexico **Partner**: Sincronia Logistica **Background**: Mexico has one of the most congested transportation systems in the world; traffic often represents a risk for emergency responders, especially when lives are at risk **Project**: Delivering health supplies from warehouses to hospitals across Mexico **Finding**: Delivery time cut down by 80%
Location: Dominican Republic **Partner**: WeRobotics, DR Drone Innovation Center, El Coco hospital, Los Montaditos (hospital) **Background**: Isolated communities across the Dominican Republic have a hard time to access quality health services. The condition is exacerbated for those living in mountainous areas where the transportation to hospitals is expensive and time-consuming. Hospitals in these remote communities neither have the infrastructure nor the supplies to deal with all the cases they receive. **Project**: Flylab - delivery of medical supplies to community hospitals

Equipment: DJI Matrice 600 Pro with a delivery box that can carry loads up to 6 kg per flight

Finding: Total of 101 flights, moving a cumulative 21.25 kg of medical supplies and blood samples for testing to the community hospitals over a two-month period

Drone application in India

The drone ecosystem within India is currently evolving with a few players manufacturing and catering to commercial use cases. However, the ability of drones to reduce the cost of compliance and technology, while also enhancing the value of the information gathered through these systems have been the key drivers for increased adoption of drones in India. Traditional approaches that are time-consuming and return inaccurate data can now be replaced by cost-effective, data-rich drones. In addition, technologies like 3D modelling, Internet of Things, artificial intelligence among other things have unlocked a world of possibilities for organisations to leverage the use of drones and its associated technologies across their operations. While specific to mobility, the application has been limited, the Government of India and several state governments have been proactive in granting permits and allowing for pilots in the space of logistics.

Table 4: Drone applications in mobility, India

Area	Uses	Applications
Logistics	• Medicine delivery • Parcel delivery • Food delivery	Delivery of vaccines and drugs by drones: An initiative by the government of Telangana started trials for vaccine delivery. Food delivery platforms like Swiggy have been given approval to deliver food BVLOS
Traffic Monitoring	• Traffic management	To prevent deaths and injuries due to road accidents, governments are using drones to monitor traffic. Their elevated use was seen during the pandemic.
Disaster management	• Rescue and relief • Data collection • Surveying and mapping	Flood Inundation Modelling using drones at Guntur, Andhra Pradesh. The use of drones proved to be extremely successful and useful in completing aerial surveys of disaster-hit areas.

Source: Department of IT, Electronic and Communications, 2021; The Economic Times, 2021; FICCI, 2017

The usage of UAVs is only going to increase as the technology itself gets more advanced as well as accessible to the average consumer. In the current scenario, governments and large private players are exploring the possibilities drones offer. With regulations evolving in the nascent Indian industry, drones may well grow rapidly and become vital components in the field of mobility. With the government easing regulations and permitting trials for BVLOS operations, drones hold tremendous promise to transform everyday life in India.

Table 5: Drone testing in India		
Organisation	Area of application	Impact
ICMR	Vaccine Delivery	Delivery of vaccines from Bishnupur to Karang in 32 minutes and Bishnupur to Phayeng in 30 minutes. Altogether covered almost 50km aerial distance in approximately 60 mins, which otherwise is 90 km by road taking approximately 7-8 hours to travel.
Skye Air Mobility	Medicine Delivery	Delivery of vaccines with a payload of 1.5 Kgs at a distance of 3km within 7 minutes flying at 400 meters
Government of Telangana and Marut Drones	Afforestation project - Hara Bhara	This is a first-of-its-kind initiative where the state government will be planting 50 lakh trees across 12,000 hectares of land in forests in all the 33 districts of Telangana.
IFFCO	Spraying of Nano Liquid Urea	More effective on crops and has a positive effect on productivity.

Source: Desai, 2021; Janyala, 2021; PIB, 2021a

India's drone market

India accounts for 22.5% of the world's UAV import and tops the list of drone-importing nations (Mallapur, 2015). While, majority of these are for military purposes, commercial drones are showing healthy growth as well. According to a study conducted by BIS Research, it is predicted that the market for commercial end-use of drones might supersede the military market by 2021, cumulatively hitting approximately US$ 900 million (PwC & Faraz, 2018).

India could be one of the countries at the forefront of the drone revolution. The global drone market size is expected to grow to US$ 42.8 billion by 2025 at 13.8% CAGR (DRONEII, 2021). India is expected to be the third-largest drone market in the world by 2025. Though both the industry and the market in India are at a very nascent stage, several companies across industries are prioritising the use of drones to improve their operations and expand their business (DRONEII, 2021).

Universities and technology clusters are already producing startups that build and use drones; India has at least 50 drone start-ups operating with increasing room for growth and innovation. There are more than 100 drone manufacturers, with more than 200 drone service providers and over 1 lakh drone pilots in India (Business Standard, 2021). The drone sector is set to generate 5-7 lakh job opportunities with the use cases traversing agriculture, mining, construction, traffic monitoring etc.

Drones have great potential to transform India's urban mobility. With the advancement of technology, the production of drones is expected to become economical. While technologies such as AI, blockchain and cloud are being adopted by the state, the government is also realising the potential of drones, working towards democratising the sky, and enabling new participants in aviation.

A review of worldwide regulations, i.e. key enablers of drone technology

Technology has created sophisticated drones that not only fly faster but are also equipped with hovering technology. As drones come with enhanced capability, regulatory aspects need to be coherent to extract the full advantage of drones. Liberalised regulations and heightened use cases are resulting in a rapid rise in the number of permits being issued globally.

Drone rules around the world

Based on the nature and degree of restrictions, drone regulation can be broadly grouped as follows (McNabb, 2020).

1. Outright ban: Countries do not allow drones at all for commercial use.
2. Effective ban: Countries have a formal process for commercial drone licensing, but requirements are either impossible to meet or licenses do not appear to have been approved.
3. Visual line of sight required: Drones must be operated within VLOS of the pilot, thus limiting their potential range.
4. Experimental visual line of sight: Exceptions to the constant VLOS requirement are possible with certain restrictions and satisfactory pilot ratings.
5. Restrictions apply: Drones need to be registered, and/ or additional observers are required.
6. Unrestricted: Drones can be flown around private property and airports, and under 500 feet (150 meters).
7. No drone-related legislation

Table 6: An overview of countries categorised by regulation

Regulations	Countries
Outright ban	Argentina, Barbados, Cuba, Morocco, Saudi Arabia, Uzbekistan, Syrian Arab Republic, Senegal, Nicaragua, Madagascar, Algeria, Brunei, Côte d'Ivoire, Iran, Iraq, Kuwait, Kyrgyzstan
Effective ban	Algeria, Belarus, Chile, Colombia, Egypt, Kenya, Nigeria, Maldives, Malaysia, Gibraltar
Restrictions	~27 countries
Visual line of sight required	~50 countries including India
Experimental visual line of sight	Canada, USA, UK, Ireland, France, Portugal, Spain, Germany, Poland, Czech Republic, Denmark, Finland, Russia, Saudi Arabia, China, Japan, Australia, New Zealand, Uganda, Zimbabwe, South Africa
Unrestricted	Panama, Sweden, Estonia, Argentina, Venezuela, Turkey, Laos, Vietnam, Chad
No drone-related legislation	Around 62 countries have no drone related legislations

Source: Surfshark, 2021

Regulatory frameworks for drones are constantly evolving as countries are evaluating the tradeoffs between the risks and opportunities of using drones for peaceful, commercial purposes. While some countries like Algeria, Yemen, Morocco and Iraq have imposed an outright ban, countries like Mongolia, Pakistan and most African countries have no regulation. In their midst are several countries that are experimenting with new liberalised regulations to aid faster adoption of drones.

Table 7: Key Regulations/ policy initiatives that have enabled the use of drone

Country	Regulation/ Initiative
Australia	Drone safety advocates and Civil Aviation Safety Authority (CASA) officially recognise retailers, wholesalers and manufacturers. They also aim to educate customers about the usage of drones safely. Standardised national drone safety signage to help users know where they can or cannot fly drones. CASA and Airservices Australia are piloting Digital airspace authorisations to grant permits automatically authorised through a digital portal.
China	The Civil Aviation Administration of China (CCAC) has granted permission for drones to be used for heavy-lift logistics. This opens up opportunities for scaling logistics services.
Estonia	No one-time permit required to fly a drone in an uncontrolled airspace lower than 150 metres.
Malawi	Opened the first drone corridor as a technology-friendly environment for local and international drone companies to test their solutions. The African Drone and Data Academy (ADDA) was established with an aim to equip the youth in Malawi and the African region with necessary skills while strengthening the drone ecosystem for more effective humanitarian and development response.
South Korea	A K-drone Traffic Management System is being developed with state financing of $22 million. The basis of airborne traffic management is a three-stage, vertical zoning system that de-conflicts aircraft, flying taxis and drones. South Korea has also incorporated a Drone Division within the Ministry of Transport. This will help promote and adopt drones under the aegis of an established department.
Sweden	Flying in the dark, unmanned aircraft shall be equipped with lighting in such a way that the position and direction of the unmanned aircraft can be clearly understood. This is to ensure safety. Need for mandatory permit before sharing, uploading, spreading or selling images, video or other material that in some way depicts Sweden's land areas from the air. This to protect privacy and ensure individual and national security.

UK	The Civil Aviation Authority (CAA) has set up a virtual space where companies can test their drone technology. UK Civil Aviation Authority (CAA) has also set up a Regulatory Sandbox to develop and test a Concept of Operations (CONOPS) that defines the airspace design, procedures, and infrastructure for safely integrating new types of operations into low-level airspace.

Source: Estonia's Civil Aviation Administration (ECAA), 2019; Civil Aviation Authority, 2020; Civil Aviation Safety Authority, 2020; Smart City Korea, 2020; Transport Styrelsen, 2020.

As commercial applications of drones go beyond photography to include mapping, data gathering, and delivery services among other things, it calls for regulations that not only enable drone usage but also ensure safety and security. Governments are beginning to respond by building a comprehensive set of regulations for ensuring the safe, secure, and sustainable use of drones.

Drone rules in India

Drone regulation in India has seen multiple iterations over the past few years, with a lukewarm impact on the technological development front. This was further accentuated by a blanket ban on civilian drone operations in 2014 by the Directorate General of Civil Aviation. It was only in 2018, with the introduction of the National Drone Policy, that graded activities were permitted in the commercial space.

In 2021, the Ministry of Civil Aviation (MoCA) released *The Drone Rules, 2021*, and thereby ushered in a liberalised era of drone governance, giving wings to a drone-powered country. Built on the premise of trust, self-certification, and non-intrusive monitoring, the objective of the new rules is to enable more types of unmanned aircraft application, increase the ease of compliance, and ensure safety and security (MoCA, 2021). In a major boost to promote the drone sector, the rules aim to make India a drone-friendly nation. Technology too plays a significant role in the adoption of the new rules. Mandatory provision such as geo-fencing, real-time tracking beacons, and no-permission-no-take-off ensure both safety and security. Further, the government has launched India's Digital Sky platform for the registration of drones and pilots, and issuance of permits for drone operations. This platform enables manufacturers to use the portal for their certification process and accessing the interactive airspace maps categorised into various zones (red, yellow, and green)[1].

Furthermore, delivery and logistics - a segment considered vital for making India a drone hub - is well recognised in the new rules. The provision of drone corridors for cargo delivery is an initiative which rightfully anticipates and prepares India for potential drone applications of the future. It is also commendable that the Government of India is setting up a Drone Promotion Council to facilitate a business-friendly regulatory regime, while also incubating new drone ideas,

[1] Green zone is the airspace upto 400 feet that has not been designated as red or yellow zones. For areas between 8-12km from the perimeter of an operational airport, green zone is the airspace upto 200 feet. No permissions are required to fly in the green zone.

Yellow zone is the airspace above 400 feet in a designated green zone. Those above 200 feet in the area located between 8-12 kilometres from the perimeter of an operational airport and above ground in the area located between 5-8 kilometres from the perimeter of an operational airport would be considered as yellow zones. Drone operations in the yellow zone require permission from the concerned air traffic control authority.

Red zone is the 'no-drone zone' within which drones can be operated only after acquiring permission from the Government of India.

business models, and most importantly, technologies. The council is also tasked with involving industry experts and academic institutions in policy advice indicating a move toward a holistic drone ecosystem for India. The latest rules give impetus to the drones sector to transform hyperlocal logistics and deliveries. As technologies advance, drones could even eliminate the extra trip from warehouses to local distribution centres thereby providing a cost and time advantage to businesses. A push to promote "Make in India" in the Drone Rules highlights the vision of the Government of India for the future of drones in the country and elsewhere.

Offering further impetus to make India a global drone hub by 2030, the Government of India has implemented a production-linked incentive (PLI) scheme for drones and drone components. A budget of INR 120 crores is earmarked for manufacturing drones and drone components in India over three financial years starting 2021-'22. Notably, the allocated amount is nearly double the combined turnover of all domestic drone manufacturers in FY 2020-21 (PIB India, 2021b). This policy push with the necessary fiscal incentive is a landmark step towards the country realising the collective vision of an *Atmanirbhar Bharat*.

As the Ministry of Civil Aviation notes in its press announcement, "*Drones offer tremendous benefits to almost all sectors of the economy. These include agriculture, mining, infrastructure, surveillance, emergency response, transportation, geo-spatial mapping, defence, and law enforcement to name a few. Drones can be significant creators of employment and economic growth due to their reach, versatility, and ease of use, especially in India's remote and inaccessible areas. The PLI scheme comes as a follow-through of the liberalised Drone Rules, 2021 released by the Central Government on 25 August 2021. The PLI scheme and new drone rules are intended to catalyse super-normal growth in the upcoming drone sector. Thanks to the new rules and the incentive scheme, the drones and drone components manufacturing industry may see an investment of over INR 5,000 crore over the next three years. The annual sales turnover of the drone manufacturing industry may grow from INR 60 crore in 2020-21 fold to over INR 900 crore in FY 2023-24. The drone manufacturing industry is expected to generate over 10,000 direct jobs over the next three years. The drone services industry (operations, logistics, data processing, traffic management etc.) is far bigger in scale. It is expected to grow to over INR 30,000 crore in next three years. The drone services industry is expected to generate over five lakh jobs in three years." (ibid)*

Indeed, the role of policy and regulations as key enablers of the growth of the drone industry cannot be emphasised enough. The following tables highlight these enablers and also outline a few challenges with mitigation strategies.

Table 8: Enablers in Indian drone regulations

Enabler	*Impact*
Permit coverage	Coverage of drones under the new rules has increased from 300 kg to 500 kg. This will also cover drone taxis. Keeping in mind the future of urban mobility that envisions air taxis and larger delivery payloads, this comes as a forward-looking and landmark development.
Single window Clearance	Digital Sky platform of the Government of India shall be developed as a business-friendly, single-window online system. With minimal human interface, most permissions will be self-generated. This is a welcome move away from licensing hurdles of the past.
Drone Promotion Council	With a focus on increasing the ease of doing business, the Drone Promotion Council seeks to create a trade body industry and academic experts for policy advice, to foster a business-friendly regulatory regime.

Zoning	The Yellow Zone, flying over which requires permission of the air traffic control authority concerned, has been reduced from 45 km to 12 km from the airport perimeter. This allows for wider operability of drones.
Certifications/ licensing	With only 6 certifications and permits required, drone operations have become relatively easy to operationalise.

Source: Ministry of Civil Aviation, 2021

Table 9: Challenges in the existing policy and regulatory setup, and measures to overcome them

Challenges	*Way forward*
Privacy	In the absence of a law for personal data protection, invasion of privacy using drones can easily become a norm. The new rules should address privacy concerns and have strong provisions for the same.
Security	Drones can be used for cross-border terrorism and insurgency. It is important to create a robust counter drone system.
R&D	The government should explore setting up drone institutes in public private partnerships which can facilitate R&D.
Enforcement capabilities	The government should create awareness about the drone operability rules among both existing and potential drone operators to help enforce the rules.
Assembly of drone parts	Assembly of drones becomes an important aspect of drone manufacturing that requires expertise. Most parts are imported which lack the necessary skill set to put together a robust, reliable drone in the sky. The PLI scheme for drones is a welcome step giving manufacturers a big boost and for India to become *Atmanirbhar*, i.e. less dependent on import of drone components.

Source: Author

Despite the aforementioned lacunae and/ or challenge, the new liberalised drone policy showcases the progressive approach of the Government of India in promoting drones. Building on this momentum, India should begin a comprehensive exercise on drone policy and associated regulations that is likely to generate better outcomes and set a new precedent for the widespread use of technology in India, especially those with the potential to transform how the country moves, works, and lives. Learnings from policy enablers of drone-friendly nations will help overcome current challenges. Indeed, now is the time to strengthen existing policies, create comprehensive frameworks, and unlock the full potential of drones for India.

Impact of drones

Governments around the world are developing regulatory frameworks to enable safe and efficient use of drones for civil purposes and ensure seamless enforcement. However, the development of the commercial drone industry is dependent on the ability of drones to operate in a common airspace without interfering with commercial aviation. Even as the government creates this impetus, the low operational costs of drones offer several benefits paving the way for a range of applications across industries.

Drones can leapfrog first and last mile logistics infrastructure in places where transportation networks are limited. Last-mile vehicle delivery accounts for more than half of the total logistics costs. By implementing drones, fuel and labour costs can be reduced significantly even as delivery times are drastically reduced. Furthermore, it is noteworthy that drones use less energy and can reduce the release of greenhouse gasses significantly, contributing towards the climate change mitigation strategy of the world. Likewise, the impact of drones in measurable terms across many sectors is documented below.

***E-commerce*:** E-commerce has disrupted the retail business as it has eased shopping without stepping out of homes. Globally, there were 87 billion parcels delivered worldwide in 2018 and the volume is expected to hit 200 billion parcels by 2025 (Berman, 2019). Considering that 80 percent of packages for e-commerce giants are under three (3) kg, they make for an ideal case to use drones for delivery (Tavares, 2019). Europe's second-largest e-commerce firm has reportedly found that drones are suitable for express delivery within 30-minutes of the order. Their analysis indicates that the cost per delivery per drone is expected to be EUR 1.00 while the cost for the van rises to EUR 4.35. However, for same-day deliveries, vans are the most cost-effective vehicles with the cost per delivery at approximately EUR 0.14 while for drones the cost was estimated at EUR 0.59. The higher capacity of the vehicle plays an important role in its efficiency (*ibid*).

***Emergency Response*:** A prime application for drones is in the area of emergency response from gathering ground information through aerial imagery to supplying medical aid and emergency kits in inaccessible or hazardous areas. Drones tend to reduce the overall disaster response time by up to 44.46% (IdeaForge, 2020).

***Healthcare services*:** In the healthcare sector, time is of the essence. Hence, drones can be a good solution to provide faster, cheaper, and more reliable delivery services. In France, delivery of biomedical samples by drones took approximately 15 minutes on average as against 42 minutes estimated via road. In addition, the delivery by drones is also expected to be 60% cheaper. The cost per delivery by drones is estimated at EUR 1.92 while delivery by a van cost EUR 4.59 (Tavares, 2019).

***Environmental impact*:** Studies find that a one-pound package delivered by a small drone could potentially reduce greenhouse gas emissions by 23-54% compared to that of a diesel truck (Stolaroff et al., 2018). Furthermore, several comparative studies show that delivery drones are more CO_2-efficient than conventional means of transport, but this depends on a number of specific factors, as outlined below.

- When the distance travelled is short, energy requirements are low and number of recipients is small
- When the payloads are small and customers are clustered around one delivery route

These results, however, need more research on whether drone delivery will simply replace alternative delivery methods or lead to additional delivery trips (Stolaroff et al., 2018).

Impact on jobs: It is estimated that drones could replace US$ 13 billion worth of human labour and services across the transport sector. However, as against popular belief automation leads to the creation of more jobs. According to a 2018 study by the World Economic Forum, between 2018 and 2022, more than 75 million jobs could be lost as companies shift toward more automation. At the same time, 133 million new jobs will emerge during that very period, thereby resulting in a net-positive scenario (WEF, 2018). Additionally, a study by Deloitte found that automation eliminated 800,000 low-skilled jobs, but, in turn, created 3.5 million new jobs (Deloitte, 2015). This could very well be the case with drone technology as well.

Table 10: Cost and time analysis of drones

Application	Cost Efficiency	Time Efficiency
Drone medical delivery	60% cheaper	Approximately one-third of road based delivery
Food delivery (Dominos-london)	46% cheaper per delivery	Approximately half of road based delivery
Parcel delivery (Belgium)	1 vs 4.35 (30 min delivery)	7 minutes per unit delivery
Survey in the construction sector	Approximately 50% cheaper	Eliminates the need of shutting down active work sites for the concerns of maintaining and inspecting. Hence reduces time of construction.
Disaster management	*Data not available*	Drones can reduce the overall disaster response time by at least 44.46%.

Source: Tavares, 2019, and IdeaForge, 2020

Drones have immense potential to improve sustainability, particularly in the areas of mobility and sustainable logistics. Key global sectors such as transport and logistics will be transformed through their technology and services. Drones could very well be at the heart of sustainability in the coming decades.

What role can drones play in achieving Sustainable Development Goals?

According to the United Nations, around 55% of the world's population lived in urban settlements in 2018. This is expected to increase to 60% by 2030 (United Nations Department of Economic and Social Affairs, Population Division, 2019). The density of people in urban areas has increased and challenges related to mobility have become a part of the routine of most inhabitants of cities globally. Use of drones can be a cost effective, and ecologically friendly medium for reducing human activity. Drones already have a huge impact on society, government, and industry. Drones provide more reliable and accurate information to create impact at scale while monitoring pollution, air quality or areas impacted by disasters in cities. Within the field of urban transport, drones to this end can play a significant role in achieving Sustainable Development Goals (SDGs).

SDG	Drone application
SDG 3: Good health and well-being	Using drones, medical supplies and samples can be delivered faster. This can be of great value to patients - including those requiring emergency first aid in disaster-struck areas - who can get the right treatment in time and avoid health or life risks and complications.
SDG 9: Industry, innovation, and infrastructure	Drones can be an energy-efficient alternative to helicopters, when it comes to inspection of infrastructures such as powerlines, mines etc. Their versatility and flexibility in terms of maneuvering make drones a preferred choice for such operations.
SDG 11: Sustainable cities and communities	Drones can play a vital role in modernising cities and in the emergence of smart cities. From traffic monitoring to package delivery and emergency response, drones are cost-effective, responsive and flexible tools for cities and municipalities.

SWOT Analysis of Drones in India

Strengths	Weakness
• Liberalised permits • Growing demand for drones • Economical operational cost • New age solution: Although it is an evolving ecosystem, its present applications are already attractive to further its use. • Since most drones used in the logistics sector are electric and consume lesser energy than other delivery mediums, drones could be regarded as a green alternative.	• Limited range and payload: The current technology limits the flying and carrying capabilities of drones. • Reliability issues, as many models are prototypes. • Cost of drones: The cost of adding delivery drones to service requires a significant investment in the infrastructure. • Battery issues: Delivery drones easily run their battery out while delivering products. Battery technology needs to evolve further to enable delivery at scale. • Airspace management is the need of the hour.
Opportunities	**Threats**
• Growth of startups; India becoming an innovation hub • Cost-efficiency • Service to geographically challenging areas • Investment opportunities • Growing demand across several sectors • Manufacturing of drones and drone parts at scale, making India a global drone hub	• Failure to scale • Safety of the public • Drones may interfere with air traffic and cause hindrance to commercial planes • Regulatory uncertainty • Misuse of drones or theft of the product that it is carrying can be difficult and costly to overcome and the possible leak of private data can have unprecedented risks. • Drones carry the additional threat of being weaponised.

India is on the path to digitally transforming itself, planning to create US$ 1 trillion in economic value by 2025. Technologies like drones will play a significant role in helping achieve these targets. The rapid growth in the digital markets opens up opportunities for drone technologies to develop solutions with the advantage of being cross-sectoral. While drones will need to navigate the few regulatory hurdles such as airspace management and safety concerns, the opportunities with massive growth projections are plenty. The latest Drone Rules, 2021, is a step in the right direction having significant elements that can be a platform for stakeholders to build upon. With the new and liberalised rules providing the much-needed impetus for the growth of commercial drones, India is on the right trajectory setting an example for countries around the world.

Conclusion

Drones are taking to the skies at an accelerated rate, even without an established infrastructure to manage the low-altitude airspace. As the skies grow more crowded, the future growth and sustainability of drones will depend upon the emergence of a system to ensure safe and efficient operations. However, without a robust infrastructure in place, drone services cannot truly embody their true potential. For India, infrastructure, public acceptance, safety, and regulatory barriers are likely the biggest hurdles to overcome in establishing the scaled deployment of drones. As regulation keeps pace with technology it needs to remove roadblocks and unlock the full potential of drones. Public-private collaboration is needed to develop drones prioritising public safety, and while ensuring community interests are well represented.

For India to optimise the benefits from the far-reaching advantages of drones and potentially become a global leader in the UAV industry, it needs to build systems and norms that are aligned with global best practices. The existence of a conducive and consumer-friendly regulatory environment is concomitant with this ambition. Going forward, India stands at the cusp of being the frontrunner in maximising the benefits from drones. With time, the utility of drones will become more defined and refined. Considering the current scenario, the utility of drones is picking up traction in niche segments of urban mobility showing a positive impact on the adoption of drone technologies that only demands impact at scale. The state must play an anchoring role complimented by industry and other stakeholders.

As technology advances, drones will be pivotal for accelerating development towards the next stage of the UAM ecosystem - Air Taxis. The future is in the skies as urban "air" mobility becomes the new reality and way of life.

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