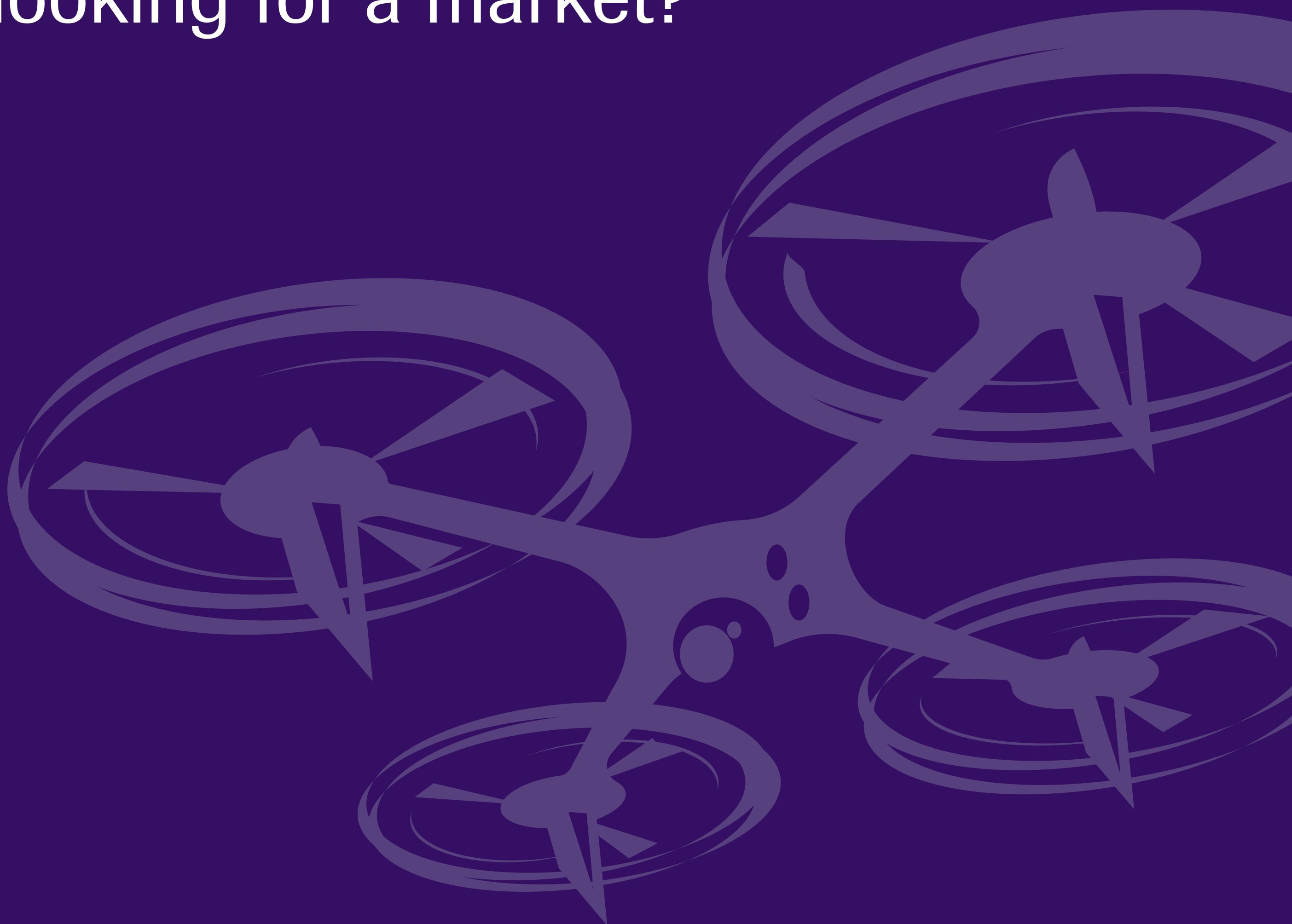
The Chartered Institute of Logistics and Transport

UAV and UAM

New aviation technology looking for a market?



POLICY PAPER

Executive summary

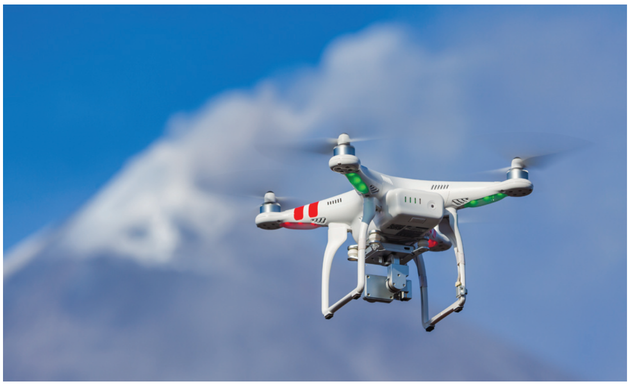
Aviation technology has constantly changed since the beginning of manned flight and some of the most recent changes involve small, sometimes unmanned, aircraft using new technologies including on-board electricity (batteries) and automation. This paper seeks to describe these developments in terms of their safety, security, environmental effects, markets and economics.

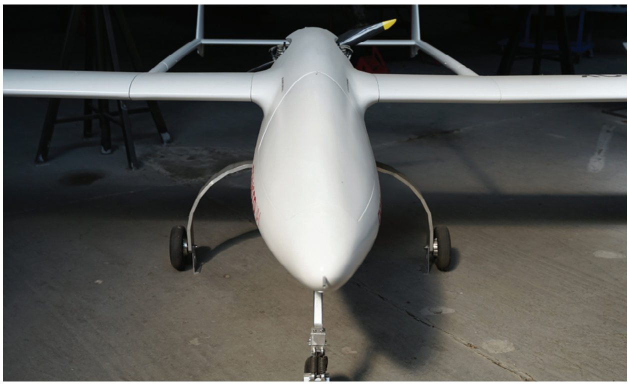
Following an Introduction, the paper discusses some preliminary considerations including defining the two main types of technology covered in the paper, as follows:

Unmanned Aerial Vehicles (UAVs) are, as their name implies, pilotless (although they may have a remote human controller) and are sometimes known as drones. The definition includes military drones but, although this paper focuses on civilian use, the technology may be similar in both military and civilian applications. A subdivision of this definition is based on size and propulsion. Smaller drones are usually powered by battery/electric engines and have Vertical Take Off and Landing (VTOL) capability. Larger drones may be powered by piston (or even jet) engines and have longer range and require a runway.

Urban Air Mobility (UAM) is a generic term to include electric air taxis and other small aircraft which can operate with small payloads (eg. up to 6 passengers) over short ranges (eg. up to 100km). UAM could be extended to cover larger and longer range aircraft (for example as described in the CILT paper on Routes to Net Zero) but in this paper we restrict consideration to smaller types. One aspect of this type of technology is that it usually involves vertical take off and landing (VTOL).

There are several different types of UAV with a range of uses. Several trials have taken place and more are planned. The paper notes that safety and environmental concerns will have to be overcome before the more widespread use of UAVs can be implemented and, for freight activity, the economics have to be compared with conventional delivery methods (van, bicycle). The most likely area of operation for freight would be remote or island routes.

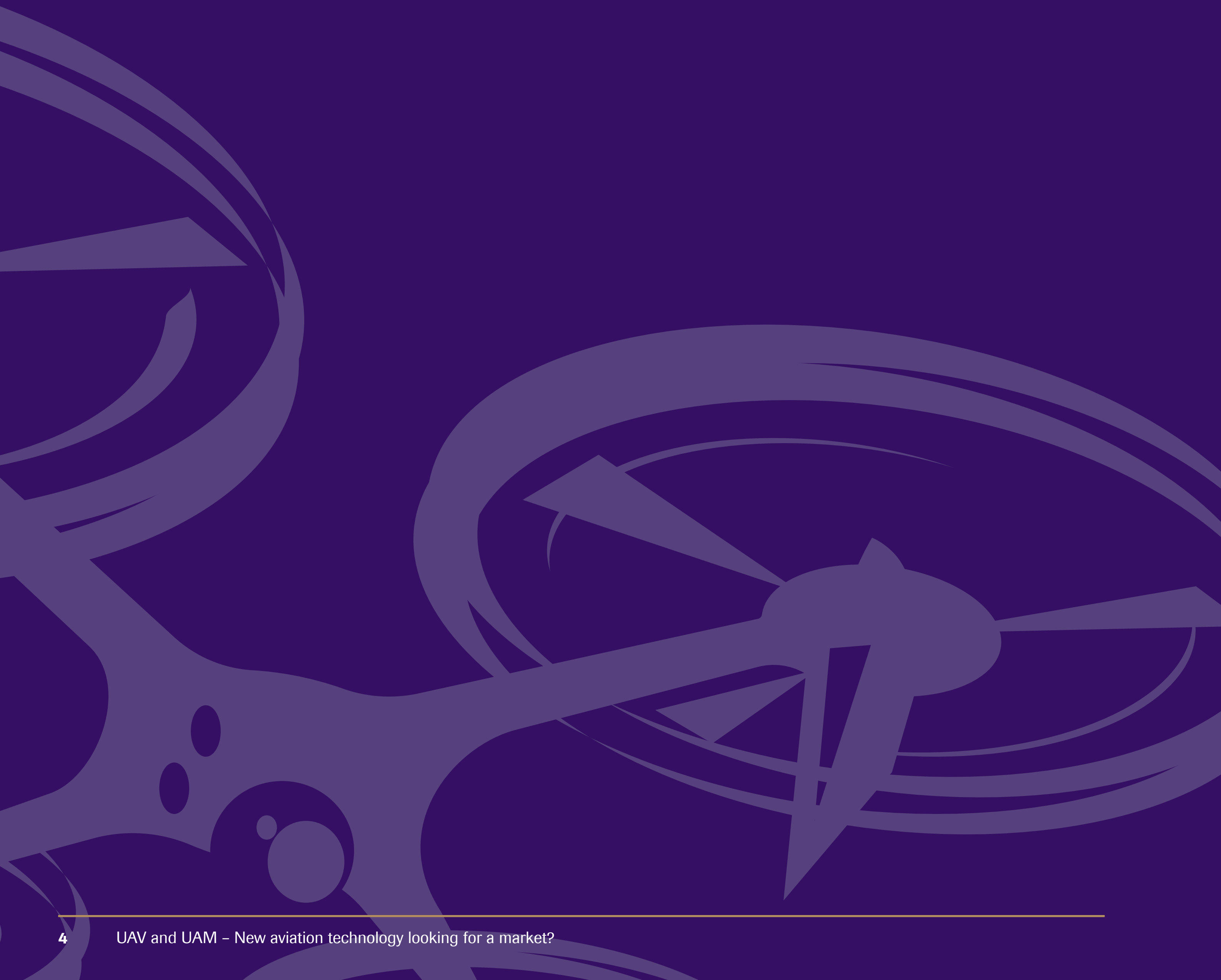




UAM is a much less developed technology, although helicopter operations have existed for many years. The difference from helicopters is in the environmental effects, and possibly economics of operation, although these have yet to be proved. Again the economics need to be demonstrated compared with the alternatives of road and rail for the types of journeys being considered.

Our overall conclusions are that, while UAVs and UAM are exciting and potentially valuable new technologies, there are many issues to be resolved before their use can become widespread.

Introduction



Aviation technology has constantly changed since the beginning of manned flight. In recent years, larger air transport aircraft seemed to have changed only subtly in shape, although this hides some significant changes in aerodynamics and materials, as well as electronics. Engines have become larger and much more efficient, but the concept of the gas turbine remains as originally invented by Frank Whittle, with the addition of by-pass technology as perhaps the major innovation nearly 60 years ago.

More recently, and driven by decarbonisation challenge, electric engines (or some form of fuel cell hybrid) have been developed alongside dramatic improvements in batteries which has meant the prospect of electric power for aircraft is now realistic, at least for small aircraft. However, for the next 20-30 years, battery electric engines are unlikely to play a significant role in medium or larger aircraft on longer routes.

Alongside electric engine and battery technology, much progress has been made in automation. Many piloted aircraft systems include automation and pilotless air vehicles are now widely available, initially for military purposes and specialised roles.

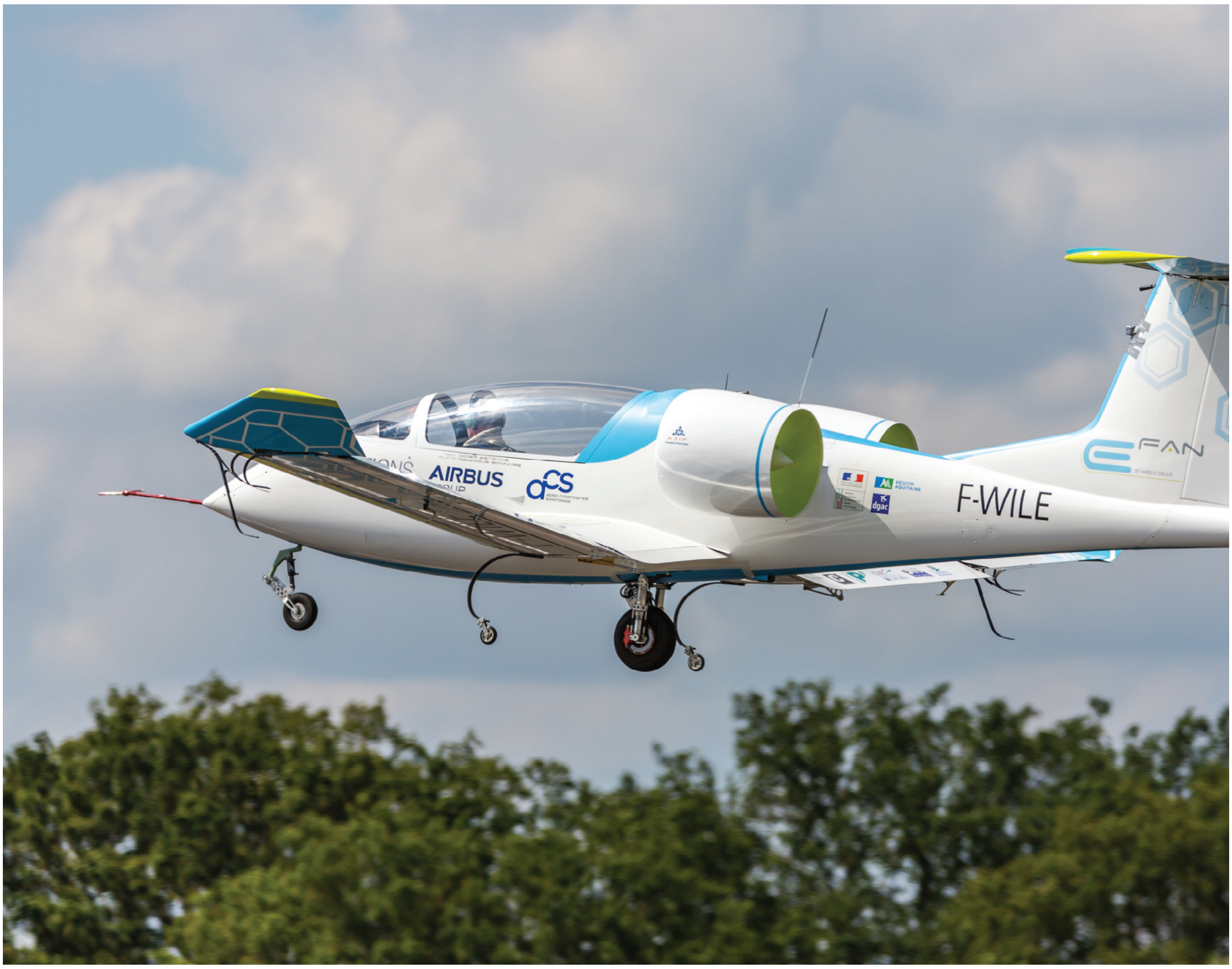
The time has now come to examine how some of these new technologies can be scaled up, not in terms of vehicle size, but more in terms of use. The purpose of this paper is to utilise CILT members' expertise to consider how realistic some of the proposals are in terms of safety, security, markets, economics and environment. Many existing operations are entirely satisfactory in these terms and this paper looks in particular at the prospects for the wider use of this new technology in two areas: logistics and passenger travel.

Useful background information on civilian drones can be found in the following reports:

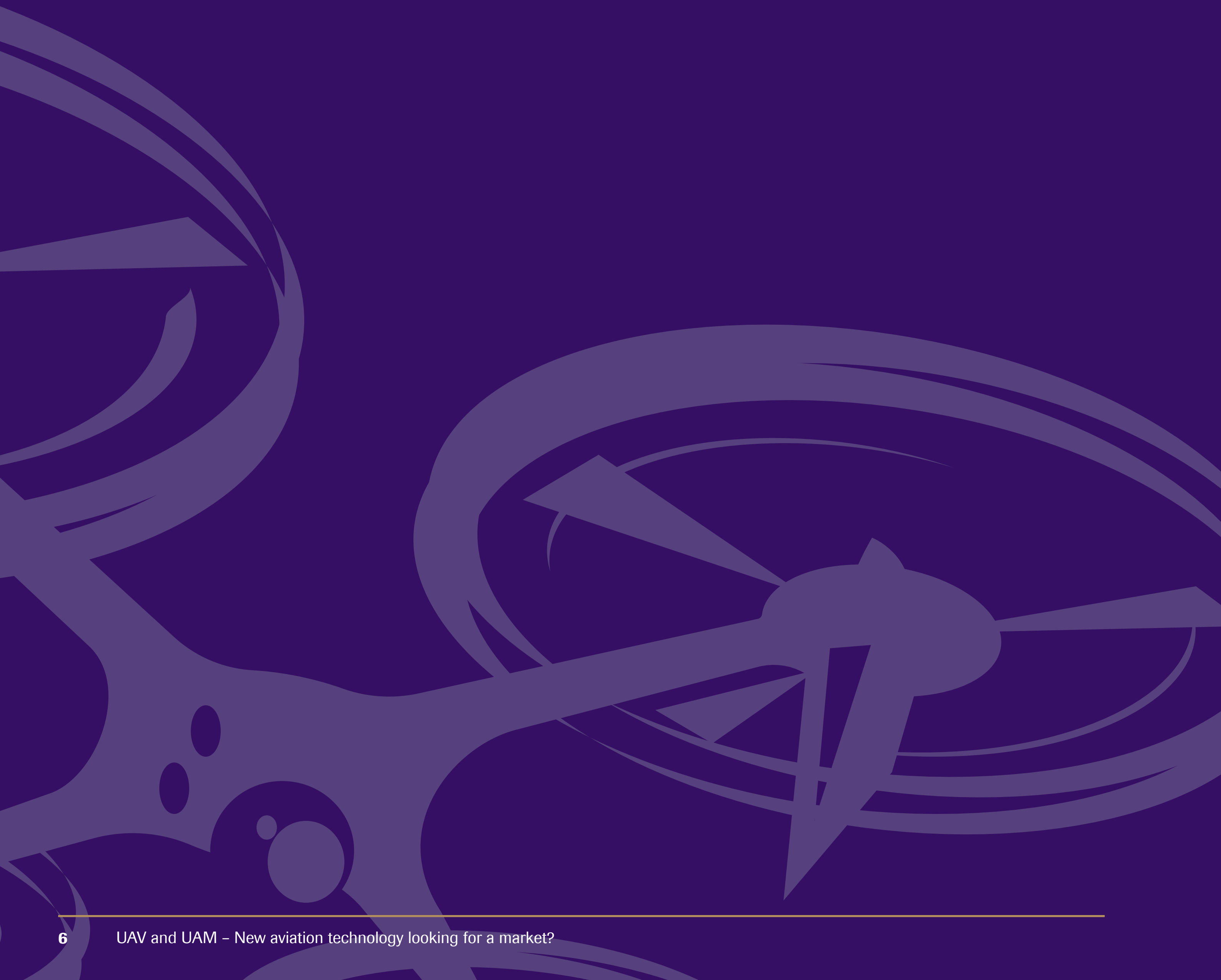
- Civilian Drones: Parliamentary Office of Science and Technology Note 479[1]
- Civilian Drones: House of Commons Library Briefing Paper CBP 7734[2]

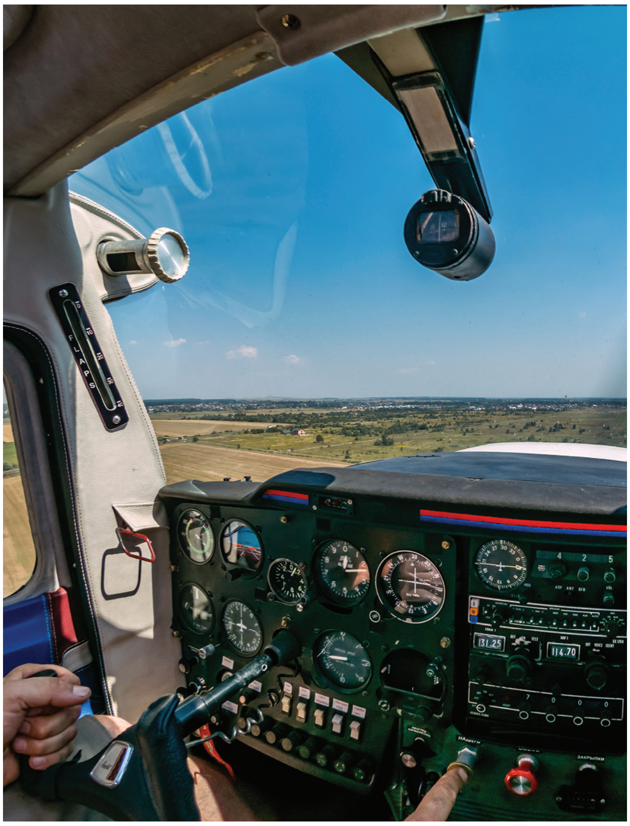
The structure of this paper is as follows:

- Preliminary considerations
- Unmanned Aerial Vehicles (UAVs)
- Urban Air Mobility (UAM)
- Conclusions



Preliminary considerations



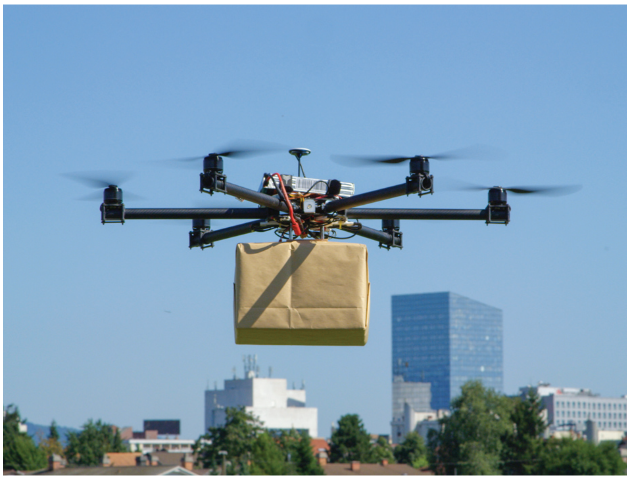


Airspace has three physical three dimensions plus time. The principles are the same worldwide although some larger countries have much greater areas of ‘uncontrolled’ airspace. Uncontrolled Airspace is the basic level, but even here aircraft are not permitted to fly anywhere. Except around larger airports, aircraft may fly up to 2,000 feet above ground level (agl) without direction from the ground but there are some basic rules of the air, such as the principle of ‘see and be seen, and avoid’. At higher altitudes there is the ‘semicircular’ or ‘hemispheric’ rule which requires aircraft to fly at certain altitudes depending on their direction. Currently, civilian unmanned aerial vehicles are permitted to operate up to 400 feet agl and in line of sight, with restrictions on their use around airports and other sensitive locations. In Controlled Airspace such as around airports, the rules are much stricter and generally require the much greater use of routes, instruments and communications.

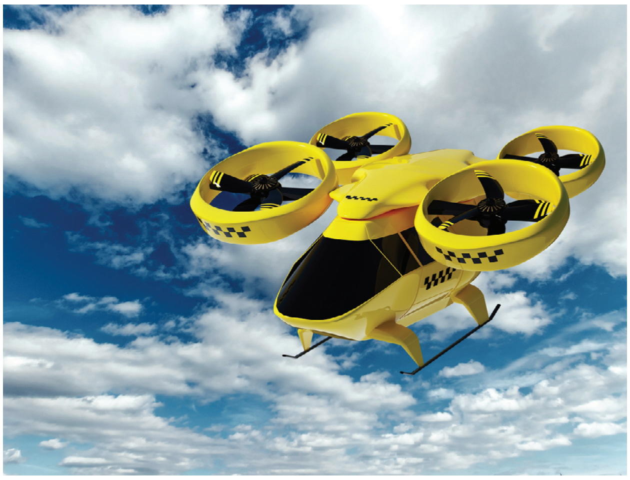
Aviation safety and airspace is covered by much legislation and regulation some of which is referred to in the House of Commons Library report noted above: the most recent legislation relevant to this report is the Air Traffic Management and Unmanned Aircraft Act 2021[3]. The CAA also has extensive documentation on drones[4]. Urban Air Mobility is currently managed through legislation and regulations for general aviation activity (in particular, for helicopter operations) although it is recognised that this many need to change to enable more extensive activity.

Two key definitions are required at this stage which are used for this paper.

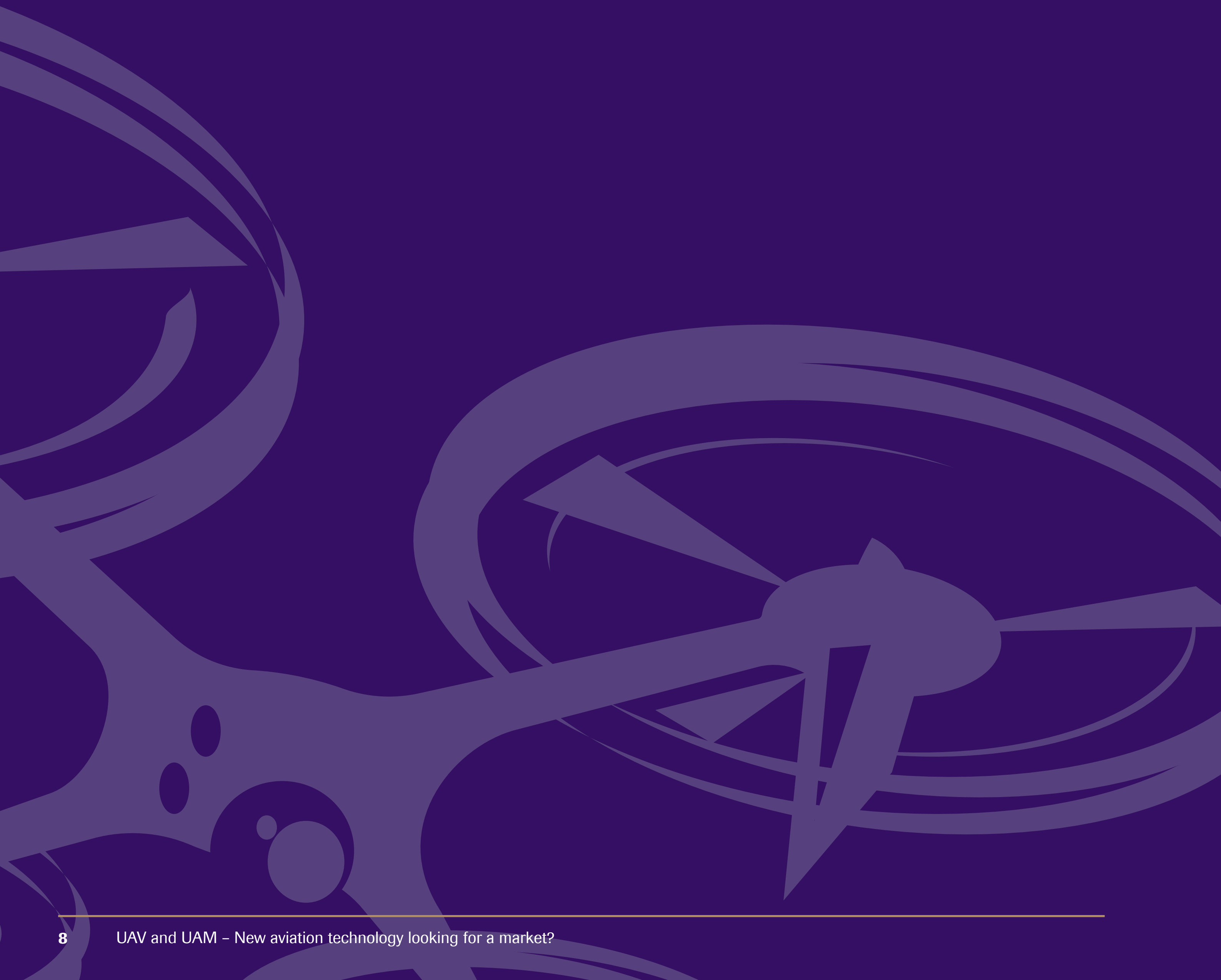
Unmanned Aerial Vehicles (UAVs) are, as their name implies, pilotless (although they may have a remote human controller) and are sometimes known as drones. The definition includes military drones but, although this paper focuses on civilian use, the technology may be similar in both military and civilian applications. A subdivision of this definition is based on size and propulsion. Smaller drones are usually powered by battery/electric engines and have Vertical Take Off and Landing (VTOL) capability. Larger drones may be powered by piston (or even jet) engines and have longer range and require a runway.



Urban Air Mobility (UAM) is a generic term to include electric air taxis and other small aircraft which can operate with small payloads (eg. up to 6 passengers) over short ranges (eg. up to 100km). UAM could be extended to cover larger and longer range aircraft (for example as described in the CILT paper on Routes to Net Zero) but in this paper we restrict consideration to smaller types. One aspect of this type of technology is that it usually involves vertical take off and landing (VTOL).



Unmanned Aerial Vehicles (UAVs)



Types of UAV

Figure 1 shows a number of different types of UAV. Several have multiple rotors, each with a small electric motor, or they could be like an unmanned helicopter or small aircraft. Many of these types can be bought as 'models' (or for use by hobbyists). One of the key technologies involved is automatic stabilisation. Multiple rotors make this possible and the systems also enable the UAV to compensate for wind. Those with a fixed wing require a runway although this may be a very short grass strip and can have a payload of up to 350 kg[5]. Control is provided by a radio connected control box which may include a joystick or a combination of up/down, left/right and forward/back buttons. They can include a camera which assists with piloting.

Some UAVs are fitted with systems which prevent them from flying in restricted areas, known as 'geofencing'. Other automation can be systems to 'find your way home', 'follow a fixed flight path', and collision avoidance.

Uses of UAVs

UAVs have multiple civilian uses, including inspection (eg. of power lines, railways, buildings), agriculture, surveying, aerial photography (eg. for media or film/TV), fire spotting and policing. All of these activities are normally undertaken by professional licensed operators, either working directly for the organisation or as a contractor and tend to be line of sight. One use which is currently experimental is for parcel delivery. Trials have been done of delivering supplies for the NHS in the Isle of Wight, and by parcel delivery companies including DHL and Amazon. These latter experiments have required flying beyond line of sight, including of course the landing and drop off.

The costs of operation are relatively modest, in terms of acquisition, fuel (ie. electricity) and manpower to operate, but the payloads are generally small. The largest fixed wing types may be able to carry 350 kg (about half the payload capacity of a small van), but VTOL types are usually limited to 20 kg (equivalent to the hold baggage allowance on passenger flights). This can be compared with a Transit type van which can carry around 1,000 kg. This immediately implies that a UAV would have to make multiple separate journeys to deliver the same amount of parcels as a van.

Electric UAV range is also limited by battery capacity. Again there are exceptions, but many drones have a range equivalent to around 30 minutes return flight, which at a speed of 30 km/h implies a range of 7.5 km. As with all aircraft, there is a trade off between range and payload. Clearly this range is significantly less than a van, which also does not need to return to base to refuel. Piston engine fixed wing UAVs may have a range of 2000 km, equivalent to a piloted aircraft.

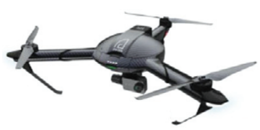
Given the payload and range limitations, depots from which UAVs can operate will need to be distributed widely. Depots could be located in many towns and cities and serve those urban areas, but rural locations would require a large number of take off points, which would be less economical. There may be opportunities for routes with short sea crossings where the alternative is a slow ferry link. Fixed wing UAVs will require an airstrip.

Consideration will also need to be given to the receiver of the delivery. Clearly the receiver location will need to be suitable for a landing, release and take off, ideally in a private space. There will also be a question of whether the receiver needs to be present to accept the delivery. Comparisons with current van deliveries show that there is a need for flexibility which may not be possible with UAVs.

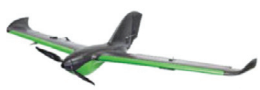
'Skyway' is a concept being developed by Altitude Angel and is a drone superhighway of 270 km (165 miles) connecting Reading, Coventry, Milton Keynes, Rugby and Cambridge[6].

Figure 1

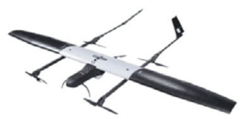
UAV classification based on wings and rotor



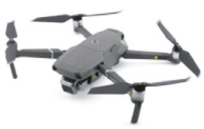
Tricopter



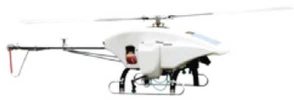
Fixed wing rotor



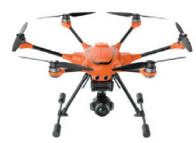
Fixed wing hybrid VTOL



Quadcopter



Single rotor



Hexacopter

At present the economics of the widespread use of UAVs for freight/parcels is difficult to understand. The costs of acquisition and operation may be relatively modest, but the market is difficult to envisage. Current parcel/freight delivery is undertaken by mass produced vans operated by regular drivers and, given the payload and geographical capability (they can operate wherever there is a road), delivery costs are generally low. Only where such costs are high, for example where a sea crossing is required, would the advantage of a UAV become apparent. UAVs may also become more worthwhile if a shortage of delivery drivers that has been seen previously becomes permanent.

Current status of trials

Trials have been undertaken by DHL, Amazon, Walmart and the NHS. DHL's programme[7] has now been ended for reasons not publicly stated. Amazon initially considered a trial in Cambridge, UK, but is now preparing for deliveries in the US[8]. Walmart's plans are for select markets in Texas, Arizona and Florida[9]. Trials appear to be more successful in rural areas where noise issues are of less concern and the alternative road journey to the nearest store or depot would be significant. The NHS trial noted above uses a particular route[10]. The indications are that the focus may be moving away from deliveries to individual properties towards the 'middle mile' which is the route between distribution centres where premium rapid distribution is required

Safety

Safety is paramount in all aviation activity and, as noted above, UAVs can include systems to help ensure safety but will have to demonstrate that required levels are workable in practice. UAV safety can be considered under the following headings:

- Avoiding collisions with UAVs
- Avoiding collisions with other aircraft
- Avoiding damage or injury on the ground or to near-ground (eg. power or communications cables)

Avoiding collisions with other UAVs will require the inclusion of collision avoidance systems similar to those in other aircraft, albeit much smaller given the lower speeds and better manoeuvrability of UAVs. It would also be appropriate to instigate fixed UAV routes (in three dimensions) although this may require longer journeys than straight line routes.

Avoiding collisions with other aircraft will be particularly significant if the ceiling of UAV operations is raised above 400 feet, where many General Aviation

operations take place outside of Controlled Airspace. Whilst the UAV may be able to recognise a conflict and take avoiding action, the pilot of another aircraft may react unpredictably (as humans do) or may not be able to react in time given the higher speed and lower manoeuvrability. Clearly UAVs should be geofenced in areas around airports to ensure no conflicts occur where air transport operations take place, and where larger aircraft have no change of taking avoiding action.

Avoiding damage or injury on the ground will require a UAV to follow ground contours and building heights and to avoid cables and power lines, and to demonstrate reliability of motors and rotors such that it does not enter into uncontrolled descent.

The CAA, the UK's aviation safety regulator, has already considered many aspects of UAV operation and is consulting, arranging trials and changing regulations as required. A particular example is Beyond Visual Line of Sight (BVLOS) operations, which the CAA is currently addressing as well as trials of the reaction time in real time operations. It is not clear how much consultation there has been with the GA community and there are clearly concerns among this group. For example, at smaller airfields, airspace discipline might not be robust enough to mix with autonomous or remote operation. Other countries' regulators and international agencies are also in the process of updating regulations.

Security

There is a potential for UAVs to be used for illegal purposes and for terrorism. After all, one of the prime types of UAV is as a military vehicle, either to carry weapons or for surveillance. In the wrong hands, UAVs could be a significant weapon which can overcome defences. UAVs may also be used for illegal surveillance of secret installations or activities. There is also a question of whether UAVs are susceptible to hacking either to steal the delivery or to cause it to crash. Drone security issues are discussed in Yaacoub et al. (2018)[11]. The Unmanned Aircraft Systems Authentication System (UASAS) project, under the Connected Places Catapult, seeks to address some of the security issues.[12]

Environmental effects

Given that they are electric, there should be a positive effect of UAVs wherever they replace a trip that is currently undertaken by a fossil fuel-powered vehicle (provided the electricity comes from green sources).

Potential adverse effects are primarily noise and intrusion. Electric UAVs are inherently significantly less noisy that piston- or jet-engined types, and multi-rotor UAVs are also less noisy than single rotor helicopters in terms of rotor noise, not least because UAVs are generally much smaller. Nevertheless, flying at low level, the electric motor noise will be heard and, of course, the noise will be heard at the UAV take off and landing points. There have been several studies of UAV noise and Schäffer et al (2021)[13] is a comprehensive review of many studies. It concludes that:

"*The literature of drone noise effects on humans is still very scarce. Nevertheless, the current literature provides a fairly consistent picture, suggesting that drone noise is substantially more annoying than road traffic or aircraft noise due to special acoustic characteristics, in particularly pure tones and high-frequency broadband noise.*"

It is possible that some of the trials noted above by DHL. Amazon and Walmart have ended or moved location because of complaints about noise, particularly in urban areas.

Experience from aircraft noise studies is that new aircraft noise gives rise to more complaints than the same level of existing noise. Thus, when new flight paths are introduced, there is often a significant adverse reaction which is not compensated for by a positive reaction to a reduction of noise levels elsewhere. This may explain part of the greater level of annoyance from drone noise, as it is a relatively new phenomenon.

Intrusion is linked to noise but carries with it a visual connotation. It is also linked to concerns about privacy and perhaps also to perceptions of safety or security.

Other environmental effects, such as air quality, climate change and surface access, are relatively minor because of the small scale of the vehicles and their electric power.

Training

CILT has made initial contact with the Future Flight Challenge team in UK Research and Innovation and one of the issues discussed was the need for logistics training and education for drone operators. This is currently being considered by the CILT Education and Professional Development Team.

Conclusions on UAVs

UAVs are well developed from their initial military and hobby uses and have many existing uses which are generally satisfactorily controlled and operated. Their potential for further use, in particular in logistics, is a step which requires more answers to a number of questions, including:

- Can they be operated safely?
- Can they be operated from depots to delivery addresses?
- Will noise and intrusion effects be acceptable?
- Will the costs of operation be comparable with other modes, in particular vans?

Until these questions are answered satisfactorily, predominantly by trial operations, the prospects for widespread UAV use in logistics seem limited. There is also a need to identify unintended consequences which only become apparent in real operational trials. There are places where operations would be appropriate, for example in remote locations or to islands, where the alternatives are limited or expensive, and where airspace conflicts are also limited.

Urban Air Mobility (UAM)

Design and Operation

In this paper, we discuss UAM as the operation of small, electric powered aircraft of 4-6 seats over relatively short distances (up to 50 km) with VTOL capability. This type of operation is sometimes known as air taxis. Some definitions of UAM include small conventional aircraft with fixed wings which, by definition, require some sort of runway, but this is not discussed in this paper.

The illustration at the beginning of this section shows a typical UAM vehicle. Its key features are electric power, VTOL capability, 4-6 seats and short range. It may have some fixed wings and also forward propulsion as well as its vertical rotors. The fuselage would be lightweight and it would include all the latest electronic and automatic systems, but it would be piloted, even if the pilot relies on many autonomous systems. The vehicle is significantly larger than the UAVs discussed above and has a payload capacity of around 500 kg. A typical cruising speed might be around 180 km/h. In some respects this would be similar in size and speed to a helicopter, although the propulsion system is very different. This type of vehicle is still in the early stages of development (unlike UAVs which have been in operation for some years) but the systems are evolving rapidly.

The U in UAM stands for Urban, and the main market for this type of activity is seen as short distance trips within or around urban areas, which are relatively short, maybe 10-20km. One type of trip often quoted is the origin to airport or airport to destination trip. This has been done in very limited circumstances by helicopters, but the cost, airspace and environmental effects of helicopters make this a rarity. A key advantage would be the ability to avoid road congestion, or the waiting time associated with the fixed schedules of public transport. However a study by Rothfield et al. (2021)[14] of potential time savings in European and US situations indicated that such time savings would be limited.

The promoters of this type of UAM note that there are numerous locations where such vehicles could operate in both urban and rural areas. A conceptual design for a 'Vertiport' has been prepared for a location in Coventry and was demonstrated in 2022 to show the size and type of facility. They could also be located on building roofs or other sites. Like heliports, they need only a small land area (single numbers of hectares), although space would be required for the aircraft to park while charging, for feeder road vehicles and the limited terminal facilities. The concept of a taxi is that it provides an on demand service, and this paper assumes that this is what is proposed. Road taxi operation is notable for its flexibility but, in part, this requires 'ranks' of waiting vehicles.

Legislation and regulation

The FAA has issued interim guidance on Vertiport Design[15]. EASA has also published information on vertiports[16]. Thus far the UK CAA has not published any guidance on UAM.

Market and business case

A comprehensive review of UAM articles is provided in Garrow et al (2021)[17]. It concludes that:

"*Research and interest in UAM have grown exponentially over the past five years, but significant questions remain with respect to whether UAM will become the next disruptive technology in urban transportation.*"

It also asks several questions, including:

"*Will there be demand for an eVTOL air taxi service and, if so, which business cases make the most sense—commuting, business shuttles to an airport, or other trip purposes?*"

A recent study for Regional and Business Airports suggested that there are 390 potential routes in the UK for Advanced Air Mobility, excluding the larger airports, which could serve 5 million passengers per week[18]. This includes conventional take off and landing aircraft so is beyond the scope of this paper, but it is argued that, as many of these journeys are currently made by car, there could be a significant environmental, as well as economic benefit. NASA has been studying the situation in the US context for some time[19], and the Future Flight Challenge from UKRI has also studied various markets[20].

As development of UAM is still at an early stage with costs not yet known there are few credible examples of a business case. The competition for the types of trips proposed for UAM comes from existing road and rail services. London's airports are well served by public transport but the situation around the rest of the UK is mixed, with some airports providing good rail and road links while at others these are more limited. To make financial sense, the fares charged for a UAM trip will have to cover the costs involved (unless they are bundled into a total fare), and it is not known if these costs will result in fares which match the most expensive links, usually the road taxi/limousine service.

One of the arguments made by the promoters of UAM is that, by offering a range of routes which are not currently available by air, a 'distributed system' can be created which means that passengers can avoid the larger airports. Demand between these smaller places is inevitably thinner than between larger cities but the small vehicle size could make service viable. The UK already has a reasonable network of air routes between cities away from the main hubs, although the frequency of these services tends to be limited, whereas UAM would be an on-demand service. It is possible that some domestic air routes would become less viable but the industry is dynamic enough to cope with such changes, as it has been for many years as, for example, competition between air and rail has changed.

The development of UAM is moving rapidly and, with this, potential new markets are being explored although none have yet been demonstrated in practice. Many orders or letters of intent have been placed with manufacturers and it may be that these are to ensure that, if and when the technology is established, operators are able to react quickly to new opportunities. Some of the potential markets being considered are currently operated by helicopters and it is possible that the costs of UAM could be significantly less than helicopters. Safety requirements for helicopters have to reflect their particular operating characteristics and helicopters also have specific environmental issues. If UAM is able to demonstrate advantages in these areas as well as in costs, there are clearly several market opportunities.

Safety and security

Given that UAM includes a pilot, the safety systems should, in principle, be no different from other small single crew member aircraft operations. The challenges that UAM will bring will be the much greater level of activity in urban areas. The advanced systems which are an integral part of UAM will have to ensure the required level of safety in the urban environment.

Environmental effects

As with UAVs, given that UAM vehicles are electric, there should be a positive effect wherever they replace a trip that is currently undertaken by a fossil fuel-powered vehicle. This advantage will erode as fossil powered surface vehicles decline in number.

Also similar to UAVs, potential adverse effects of UAM are primarily noise and intrusion. Electric UAM vehicles are inherently significantly less noisy that piston or jet-engined types, and multi-rotor UAM vehicles are also less noisy than single rotor helicopters in terms of rotor noise. While overflying UAM vehicles may not give rise to significant adverse effects, it will be near the Vertiports where concerns will arise, in particular if these are in densely populated urban areas. Again, as with UAVs, new UAM routes are likely to give rise to more complaints than areas with the same level of existing noise.

Other environmental effects, such as air quality and climate change are relatively minor because of the small scale of the vehicles and their electric power. Surface access may be a concern if the Vertiport leads to a local traffic issue in an already congested area, although the small number of vehicles should not add significantly to traffic levels.

Getting planning permission for Vertiports may be a challenge. Sites large enough to accommodate the take off and landing areas, apron and hangars, terminal buildings and car parking may be difficult to find in urban areas, and the disturbance element, while not nearly as severe as with conventional helicopters, will be a matter of concern.

Conclusions on UAMs

Unlike UAVs, UAM is at an early stage of development, with prototype vehicles only just achieving their first flights. Nevertheless, the principles of electric-powered, lightweight, VTOL aircraft seem to offer significant potential for new markets, provided the following questions can be satisfactorily answered:

- Can they be operated safely?
- Can a network of Vertiports be established?
- Will the time savings and convenience be attractive?
- Will noise and intrusion effects be acceptable?
- Will the costs of operation be comparable with other modes, in particular road and rail?

UAM is a radical approach to urban transport which would utilise new technology opportunities. However, it is not a mass transport mode and will be limited to markets where time, convenience and privacy are at a premium. The current mode which provides this service is taxi and limousine, where the price is high but the vehicles are subject to congestion and, increasingly, to restrictions on access. Urban rail and metro systems are competitive on journey time, but are not door-to-door. Several airlines have placed preliminary orders for UAM vehicles, and it will only be if and when these come into service that the system will be proved.

Conclusion

This paper has considered if the opportunities to use new technologies in aviation, in the form of Unmanned Aerial Vehicles (UAVs) and Urban Air Mobility (UAM) can be realised. Although these two areas are different (UAVs for freight, UAM for passengers), they share some features including electric power, VTOL and a high degree of automation, although UAM would be piloted.

UAV technology has advanced rapidly and is in widespread use in a number of areas. The question is whether their use can be extended into the logistics sector to deliver packages. There are a number of questions to be answered before the potential can be realised, but the fundamental economics, and in particular any comparison with a van-based delivery system, would suggest that the potential is limited to roles where a van is less practical, such as for remote or island locations.

UAM is much less advanced, although the principles and technology appear straightforward. The questions here also relate to the attractiveness of a system in comparison with existing modes, which suggest that the market would be limited to passengers who put a very high value on their time, convenience and privacy. However, if UAM can demonstrate cost and environmental advantages compared with helicopters, there could be significant market opportunities.

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About CILT

The Chartered Institute of Logistics and Transport (CILT) is a professional institution embracing all transport modes whose members are engaged in the provision of transport services for both passengers and freight, the management of logistics and the supply chain, transport planning, government and administration. Our principal concern is that transport policies and procedures should be effective and efficient, based on objective analysis of the issues and practical experience, and that good practice should be widely disseminated and adopted. The Institute has a number of specialist forums, a nationwide structure of locally based groups and a Public Policies Committee which considers the broad canvass of transport policy. This paper draws on contributions principally by the Aviation Policy Group.

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