Drone delivery services – the future of last mile logistics or simply pie in the sky?

Jonathan Cowie, Transport Research Institute, Edinburgh Napier University; Peter Jackson and Keith Fisken, South East of Scotland Transport Partnership (SESTrans); Mark Richardson, Ristol Consulting: Rolf Meerbach, Drenthe Province, the Netherlands; Frans Hamstra, Chief Operating Officer, Drone Delivery Services Ltd; Richard Stark, Mercury Drone Ports Programme.

Abstract
With high publicity projects such as Amazon Prime Air and Google Wing, a significant role is seen for the future use of drones in last mile deliveries. Nevertheless, many uncertainties remain. This research is entirely explorative in nature with aim of uncovering some of these uncertainties and establishing future possibilities for the use of drone deliveries. A qualitative methodology is employed based on the construction and evaluation of future scenarios through key informant interviews and a focus group. Four scenarios are developed, namely specialist deliveries, premium deliveries, milk run outliers and mass deliveries. The likelihood of each scenario is found to be strongly related to regulatory issues and the underlying economics of drone operation. In terms of the latter, key is drones poor performance with regards to route density and drop size. Where the impact of these factors is nullified, then these areas offer considerable potential for drone delivery over the last mile. In terms of the four scenarios developed, this specifically relates to Scenario 1 (specialised deliveries) and to a lesser extent Scenario 3a (piloted milk run outliers in rural areas). Considerably more evidence based research however is needed in the subject area.

Keywords
Drone deliveries; air regulations; drone economics; last mile delivery

JEL Classification Codes
R42; R48; R49

Acknowledgements
The authors wish to express their kind thanks to all research participants and their willingness to contribute their time and insights, without which this research would not have been possible. They also wish to express their gratitude to the Interreg North Sea Region Programme Secretariat for providing matched funding through the SURFLOGH project.

1 Introduction

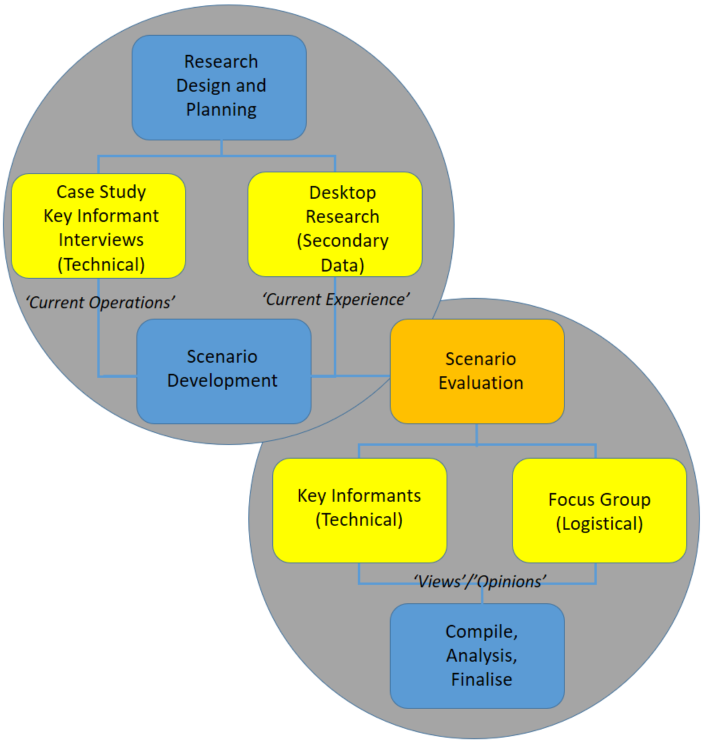
A US Postal Service survey carried out in 2016 found that the overwhelming majority of respondents (75%) expected drone delivery services to be on offer by 2021, and furthermore that 56% would see this in the form of a one hour delivery service (US Postal Service, Inspector General, 2016). Six years later, and this appears to have been a considerable overestimation of the state of drone technology at the time and a lack of awareness of some of the realities behind bringing mainstream drone deliveries to fruition. It may also in part reflect a high level of publicity with regard to drone delivery services driven by strong business interests.

The aim of this paper therefore is to attempt to look behind these issues and outline the state of affairs at present, primarily through case study research centred on recent pilot initiatives/demonstrations in Scotland and the Netherlands. From this possible future scenarios on the potential direction that last mile drone delivery services may take in the future are developed and evaluated before conclusions drawn and areas for further research highlighted. The whole premise of the current work is purely explorative in nature and seeks to collate and add to the evidence base surrounding last mile deliveries by use of drones.

2 Methodology

This research is entirely qualitative in its approach, hence seeks to obtain the views and opinions of those directly involved with last mile drone deliveries. It is also entirely explorative in its outlook. The basic approach taken is outlined in Figure 1.

Figure 1: Research Methodology



In basic terms, the methodology consisted of two phases, scenario development and scenario evaluation. These should be considered as exploratory scenarios, i.e. seek to explore a range of uncertain futures. These were developed in the first instance through desktop research and case studies surrounding pilot initiatives in Scotland and the Netherlands. There was no clear rationale for the selection of these two countries other than convenience sampling (Bryman, 2001), however without assured access to key informants the research simply could not have been undertaken. In terms of the case studies, these consisted of an initial interview with key informants (i.e. those directly involved in the projects), complemented in some cases with onsite visits and attendance at demonstrations. In addition to numerous informal discussions, in total four formal interviews were conducted, two with representatives from Scottish initiatives, and two from the Netherlands. Out of this stage four potential future scenarios for drone deliveries in last mile logistics were identified. Scenario evaluation was in two parts, firstly these were discussed with the same key informants in a short second interview; discussions were directly focused on the technical and regulatory aspects of each scenario. A focus group was then arranged which consisted of those with expertise and/or knowledge around the area of last mile logistics. This was made up of eleven members consisting of six local authority transport planners with both urban and rural freight specialisms, a town planner, a local authority business development manager, two freight transport consultants and two academics. What was sought from this particular group was a focus on logistical operational aspects, as well as potential wider issues around economic and social considerations.

3 Drone Deliveries, Issues and Research Literature

3.1 Drone Characteristics

Often called UAVs (unmanned aerial vehicles), or RPAS (remotely piloted aerial systems), Lee et al (2016) highlight there are two main types of drone, multirotor and hybrids. In terms of the former, these have an average max carrying capacity of between 1 to 2.5kg, flying range is 10 to 30 miles, and max speeds range from 10 to 40 mph. Max altitude is 100 to 400 feet. Hybrids on the other hand have fixed wing and two or more energy sources, with the authors citing a carrying capacity of around 10kg, max flying distance of 100 miles, top speed 40 mph and the max altitude at much higher than 500 feet. Whilst cited in 2016, these figures would still seem to be appropriate at the time of writing.

3.2 Regulatory Environment

All regulatory provisions regarding drone flights tie directly in with those originally laid down by the Chicago Convention 1944; this established the basic rules of airspace, security, flying rights etc. At the time of writing, throughout the vast majority of the British Isles and the European Union any commercial operation of drones in delivery service is severely restricted. This relates to both areas in which drones can be flown and the conditions under which flights can take place. Generally speaking, flights over areas of population are prohibited. They are also restricted to those that are within visual line of sight (VLOS), one pilot per drone and generally under 500m in range. Flights beyond visual line of sight (BVLOS) however offers the potential to considerably expand operations over longer distances, increase automation and thereby the number of drones that can be piloted by a single operator. Under current UK regulations however, the operator needs to apply to the Civil Aviation Authority (CAA) for an Airspace Change Process (ACP), which also requires an Operational Safety Case (OSC). Once this had been scrutinised, then the conditions under which BVLOS flights may take place are specified and segregated airspace defined, hence prohibiting other aircraft movements in the specified area. Under normal circumstances, the whole administrative process takes between six and nine months, and any such approvals are only for a temporary period, the experience so far being three months.

In terms of the potential for drone deliveries, the above represent severe restrictions and clearly some kind of change/development of the regulatory environment would need to occur before more use could be made of drone delivery services. All respondents in the course of the research however highlighted that this is a difficult issue going forward. To a large extent the onus is on the industry to prove safe operation and the ability to seamlessly integrate with other air traffic. Nevertheless, any regulatory body has to be completely risk adverse. Respondents did highlight however that certainly in the UK context, the CAA seemed to be making some positive moves, through for example the CAA Innovation Hub, the establishment of a policy team with the aim of guiding the industry and the Future of Flight programme which is aimed at building up an evidence base. There is also strong pressure to advance the technology, if for no other reason than the resulting economic benefits that could potentially accrue from doing so; the recent UK Government commissioned report ‘Skies Without Limits v2.0’ (PwC, 2022) gave the headline figure that the drone industry (across all applications) could contribute up to £45.0bn to the UK economy by 2030 with 650k associated jobs. The deeper regulatory issue however is that up until now any craft in the air is governed by the basic requirement for the pilot to be able to move left, right, up or down, and hence once things begin to move into automated flight (in whatever form that may take), this is unexplored territory. As a consequence, even with a relatively progressive regulatory body, regulatory change will be very slow.

3.3 Economics of Operation

A key consideration with regard to the potential for the use of drones in last mile deliveries is the actual economics of operation, or to be more specific, the underlying cost and cost structures of operating a fleet of drones. Along with the regulatory environment, this is key to future use. Nevertheless, estimating the costs of drone deliveries becomes problematic for several reasons. In the first, and most obvious case, the technology is still at an early stage of development (both in terms of application and drone production), and hence the feasibility of drone deliveries will be determined by future costs rather than current ones. Some element of guestimate is therefore inevitable. The second issue is that with respect to accessing relevant sources, there appears to be a high degree of hype, optimism, assumption and illusion, and therefore attempting to gain some kind of insights becomes difficult. As an example, in the course of this research 12 figures were obtained relating to the cost per drone delivery, with the vast majority based on hypothetical situations; when inflation and exchange rates were accounted for these produced a mean figure of £2.12, but a median value of £0.90. Both estimates however are considered to be underspecified, primarily due to considerable underestimations of the capital and labour costs associated with drone flight. A third difficulty is that cost will vary considerably with the level of regulatory controls, the scale of the operation and finally the geography of the area to be served. In some respects however in the current context this is less of an issue, as the aim is to examine last mile drone deliveries with a view to constructing conditional scenarios, and hence these to a degree can encompass such factors.

To return to the actual cost, an often quoted figure is from analysis undertaken by Keeney (2015), who estimated the cost of a single drone delivery to Amazon (in the US) at around $0.88 per delivery. This was based on the prime assumption that 25% of Amazon deliveries could be undertaken by drones, and hence this would result in just over one million packages delivered each day by a total fleet of 30k to 40k drones. Allowing for inflation and converting to pounds, this would roughly equate to a cost per delivery today of £0.98. Other sources (and our own experience) however suggest that such cost estimates are highly dependent on the assumptions used, and that when these vary, this can result in considerable differences. As an example, Lee et al (2016) estimated a single cost for a drone delivery to be between $9.75 and $17.44. One of the key differences from Keeney’s figure related to the number of drones that could be simultaneously piloted by a single operator, with the former study assuming this to be 10 to 12, however the latter on a straight one to one. As if to add further to the confusion, as of 2022 the costs of a single delivery for Amazon Prime Air was reported during the ongoing trial to be at least $484, and only anticipated to reduce to $63 by 2025 (Business Insider, 2022). The drones used cost $146,000 to build per unit, and had a reach of only five kilometres.

Our own research suggests that at present, the cost per delivery by drone is around 6 to 7 Euros per drop, but again this will be dependent upon the application in which it is being employed. Nevertheless, this would suggest that for the last mile segment of the market, at the moment they are uneconomic. The main reasons are that drones perform poorly with regard to route density and drop size. Hence where either a large number of deliveries are made over a short time period/small area (i.e. high route density) or a large number of deliveries made to a single location (i.e. high drop size), then the delivery cost per parcel considerably reduces. Currently, drones are unable to achieve either of these factors. This is compounded by the underlying cost structures of vans and drones for last mile deliveries, where in the case of the former most costs are variable, i.e. only incurred when in operation, but for the latter a higher percentage are fixed, i.e. capital costs. In order to achieve low unit costs therefore, drones need high route density and/or high drop sizes, but as stated at the moment both are unobtainable.

3.4 Literature Review

The general background for the future potential of drone deliveries is to be found in the significant increase in e-commerce that has occurred over the last twenty years or so. Cowie and Fisken (2023) highlight that online sales have risen from under 5% of total sales in 2007 to over 27% in 2022, and outside of a clear blip over the Covid-19 period, this has been a long and consistent rising trend over the whole period. Furthermore, Joerss et al (2016) estimate that the cost of global parcel delivery, excluding pickup, line-haul, and sorting, amounts to about €70 billion, a figure that has undoubtedly significantly increased over the last eight years. What this represents therefore is a potentially lucrative and expanding market.

As regards drone deliveries, Lee et al (2016) put forward the notion that this could offer faster delivery times, lower maintenance costs and reduced impact on the environment in comparison to traditional (van based) methods. To that, Joerss et al (2016) add that from a consumer's perspective, drone delivery could satisfy customers' expectations in terms of flexibility, security and cost. In an assessment of public perceptions of drone deliveries, the authors survey found that 25% of respondents were willing to pay for same day or instant delivery (i.e. within 2 hours), however only 2% would pay significant premiums for the latter, suggesting there may be a limited market for such services. Nevertheless, the authors use these figures to predict that 100% of all B2C items will be delivered in the future by some form of autonomous vehicle (including drones).

In a similar vein, Yoo et al (2018) examined public attitudes and intentions to use drone delivery technology based on 296 online survey responses in the US. Around seventy five percent of respondents indicated a positive intention, with the main stated advantages being seen as speed of delivery and reduced environmental impact, but only the age of the respondent (inversely), perceptions of the speed advantage and 'complexity' (i.e. ease of use) were found to have a statistically significant influence on intention to use. Kim (2020), through the estimation of a number of discrete choice models, found that positive attitudes towards drone deliveries were more prevalent in younger age groups, where items were of lower value and dependent upon other characteristics such as gender and household income. In terms of potential future demand levels, Doole et al (2020) produce three scenarios (low, medium and high) to estimate the impact this would have on air traffic density. This was specifically centred upon express and fast food deliveries. In a case study of Paris, the authors estimate that by 2035, the urban airspace of Paris will need to accommodate a traffic density of 63,596 drone based deliveries per hour. This over an area of 12012 km^2, hence just under 6 drones an hour in any given km^2. This is based on a number of assumptions with regards to parcel weights, suitability for drone delivery, delivery time, and number of possible operational days. The cost per delivery however is calculated at a 'realistic' level of €0.70, a figure entirely based on secondary sources and 'corroborated' using Keeney (2015). As such, the estimates appear to be overly optimistic.

Whilst reduced environmental impacts is often cited as an advantage of drone deliveries, the evidence on the issue is mixed. Stolaroff et al (2018) for example, using simulated figures estimated that whole life cycle energy use for package delivery by small drone was lower than ground-based delivery and hence if carefully deployed, could contribute to reductions in greenhouse gas emissions and energy use from the transport sector. Nevertheless, Figiozzi (2017) found that whilst UAVs are more CO_2e efficient than diesel vans for small consignments, such savings drastically reduce when route density increases, and emissions are considerably higher per delivery when the number of parcels that can be delivered in a single day is taken into account. Goodchild and Toy (2018) similarly found that the relative differences of CO_2e between van and UAV delivery methods vary considerably with the distances travelled and number of recipients, with drones only providing CO_2e benefits where distances are short and there are few/single stops.

Examining all of the literature above, very little exists from a supply side perspective, and those that do, are based entirely on secondary sources. As such, there is a lack of any form of primary data or direct experience, i.e. the evidence base is extremely narrow. As a consequence, what the literature overlooks are operational realities, both in terms of drone operations and last mile logistics, and in most cases completely ignores regulatory issues.

3.5 High Profile Initiatives

Whilst a divergence, in the course of the research two high profile initiatives came to light, and as such potentially provide insights into the future of drone deliveries and some of the issues surrounding these.

3.5.1 Wing Aviation, Logan, Australia

The Wing Aviation (parent company Alphabet, owners of Google) initiative is in partnership with Coles, one of Australia's largest supermarket chains, where residents in the Logan area (near Brisbane) can order up to 250 items online/via app from the supermarket's range; the item(s) are then delivered directly to their residence by drone. Since starting, other local retailers have been added to the network. Delivery charges start at AU$1.25 for a small bottle of mineral water. The company completed more than 100,000 deliveries in 2021, and were well on course to increase that to 160,000 in 2022.

Whilst impossible to verify, our own research strongly suggests that operations are based on a high profile demonstration of the concept. As regards a commercial venture, then consistent with the costings given in Section 3.3, the only feasible conclusion is that the whole undertaking is being heavily financed by strong business interests.

3.5.2 (Amazon) Prime Air

Amazon Prime Air represents probably the most extensive and highest profile drone delivery project in existence, with a relatively long history dating back to 2013. Various trial initiatives have been instigated, the most recent in some rural areas of Oregon and California offering around 30 items available for delivery by drone. Significantly however, part of the Prime Air initiative involves the development of an automated air traffic control system (ATC). Most if not all ATC systems currently in existence are entirely dependent upon human oversight in order to guide piloted aircraft through a given section of air space. In very basic terms, for every civil aircraft that is in the air, there is a human who 'knows' where it is. Moving to mass flight by drone however presents an entirely different challenge, and if the same human based system was to be applied then at best this would be completely uneconomic, and at worst unwieldy, hence increased automation would appear to be the only solution.

In direct contrast to Wing Aviation, at the moment it appears that Prime Air exists primarily as a technology project and as such has a strong focus on issues that need to be overcome in the medium to longer terms rather than seeking to make high profile short run impacts.

4 Drone Deliveries – Case Studies

The following section gives a selection of case studies of drone deliveries. The specific areas of interest are applications in Scotland and the Netherlands. These surround real life applications of existing operations, although all are either at a pilot or demonstration stage and none are on a permanent basis.

4.1 Skyports (Scotland)

Skyports Drone Services was founded in 2018, and in this context, uses drones to assist businesses to develop their logistics platforms and capture associated business data. They are not 'attached' to any single drone manufacturer. Since formation, the company have been involved in a number of trials and demonstrations throughout the UK and other parts of the world, with the most significant ones in Scotland outlined below.

4.1.1 NHS Argyll and Bute Health and Social Care Partnership (ABHSCP)

Skyports obtained funding through the UK Space Agency (UKSA) and European Space Agency (ESA) to set up a proof of concept project in association with ABHSCP. This was aimed at demonstrating the feasibility of on-demand drone deliveries across the Oban-Lochgilphead region of ABHSCP's area.

Following the approval by the CAA of an ACP (see Section 3.2 above), operations began in early 2021 with a fleet of 4 drones (two on site, two maintained as back up elsewhere) and took place over a three month period. All flights were controlled from a temporary (mobile) operations unit located in Oban and piloted by a dedicated operator. 1800 specimen high priority cases were transported between the outlining medical practices to Mid Argyll general hospital servicing 884 patients. The 'normal' procedure would have been for these to be delivered by road, specifically with these cases (i.e. high priority) by taxi, and from the Isle of Mull would have included a 45 minute sea crossing. As a consequence, the company estimates over 11640 hours were saved in terms of transport time, representing a 92% reduction. Due to the direct nature of deliveries, the company also estimated savings in terms of transport costs of around 72%.

Over the lifetime of the project, 422 flights were flown totalling 14,000 kms, with an average flight distance of just over 33km. Average number of flights per day was 15, with a daily high of 24. Operations were possible 70% of the time, inclement weather preventing flights on the other days. This however was in part as a consequence of the conditions of the regulatory approval, which included a 'reduced visibility limitation'. Hence, if the cloud level fell below 1500 feet, Skyports were not permitted to operate.

4.1.2 Blood Samples, Stracathro to Ninewells Hospital

This followed a similar set up pattern to the above, with operations beginning on 26th September 2022. These centred around the transportation of blood samples from a GP surgery in Montrose, via Stracathro Hospital (a rural/community hospital) to Ninewells Hospital in Dundee. Again four drones were used, two on site and two as permanent backup. All flight paths were over largely rural areas. Six flights a day were operated, Stracathro to Montrose (return) twice a day and Stracathro to Dundee (return) once a day. Each flight was able to accommodate up to 40 samples. Again this centred on high priority cases, hence replacing taxi operation, which given the prevailing topography of the area was over a fairly indirect route. As a result, the service enabled patients to give a blood sample and obtain their test results and medicines on the same day.

One interesting facet coming out of the Stracathro pilot, is that whilst conceptually this may be viewed as a simple repeat to the above, the reality was quite different. In this case it was working with a different NHS trust that had different ways of working and different systems. In other words, it was primarily about interfacing the delivery platform with different systems and approaches. As regards the potential for drone deliveries, this is as important as the basic operational side, referred to as 'compatibility' by

Moore and Benbasat (1991), which is the extent to which any new technology fits with current working practices.

4.1.3 Care & Equity - Logistics UAS Scotland (CAELUS2)

One final initiative involving Skyports is funded by the UK's Future Flight Fund, though which the CAELUS2 project aims to demonstrate the operation of a national network of drones for the distribution of healthcare products and medicines across Scotland. Skyports are part of a consortium made up of 16 partners, which includes airport operators, civil engineering companies (infrastructure), IT providers and drone operators. The project commenced in Dec 2020 and has now entered phase 2, which will include flight trials operated by Skyports, building on the experience gained in the above two cases. In many senses, the overall aim of the project is to take what has been to date local initiatives and examine the feasibility of putting these on a national scale.

4.2 Mercury Drone Ports Programme (Scotland)

The Mercury Drone Ports Programme (MDPP) was established in 2022 in the county of Angus with the aim of creating a centre of excellence for the development of drone technology. Angus is made up of a mix of urban and large areas of rural countryside, low density population, a significant offshore industry and relatively quiet airspace, and as such, is seen as an ideal location for such an initiative. MDPP consists of a partnership between Angus Council and DTLX Drone Solutions and funded through the Scottish Government's Tay Cities' Deal, with the objective of putting airspace in place to allow BVLOS drone flights to commence. The overarching aim of the programme as explained by Richard Stark (project business development manager) is to 'get business, the public and politicians comfortable with the idea that drone deliveries can operate effectively and safely', with the expansion and development of business models following proof of safe operation. As such, this is an economic development programme that aims to be a catalyst to attract further investment from the private sector.

An important associated development with the MDPP is that the testing of the application of drone technology presents the opportunity to develop local clean energy neighbourhoods, through integrating generation and distribution of energy systems with drone service ports as part of a wider decarbonisation strategy. As high demand electrical 'offtakers' (or anchor asset loads) with extensive supporting digital networks, the deployment of drone technology enables in the first instance local energy systems to be developed that offer the potential to decarbonise drone services. Secondly, there is also the emerging potential for this infrastructure to offer a route to enabling local energy marketplaces through storing and aggregating renewable sources to connecting with adjoining users. This approach to integrating mobility, energy and digital systems is being research through the Angus Rural Mobility Hub.

4.3 Drone Delivery Services (Northern Netherlands)

Drone Delivery Services (DDS) operations are mainly centred upon Groningen Airport, Eelde in the north of the Netherlands, with the main assignments carried out by the company to date including:

- Delivery with a drone of a heart defibrillator (AED) in Groningen Seaports (GSP) head office in the presence of a board member and a deputy from Groningen municipality;
- Demo flight BVLOS at Groningen Airport Eelde during the 6th annual Wind meets Gas event.
- A demonstration flight over the IJ (Amsterdam's waterfront) for the transportation of a takeaway meal from Thuisbezorgd in the centre of Amsterdam in the presence of the CEO of JustEat Takeaway and a top official from Amsterdam City Authority. In the course of the flight, the company examined safety and technical aspects such as 4G and 5G coverage, before analysing the results to determine the next steps in the advancement of drone delivery applications.
- Flights at and near Groningen Airport Eelde, tests for integration and flying VLOS and BVLOS; (visual line of sight, inside view and beyond visual line of sight, outside view)

- Open forum with local businesses and entrepreneurs, civil servants, councillors and citizens following a demonstration flight on Vlieland (in the West Frisian Islands) in collaboration with innovation promotional company InnoFest.

Operations to a large extent are confined by existing regulations, nevertheless DDS has succeeded in gaining experience with flights and raising public awareness as to some of the possibilities. At a regional level, the company continues to work with a consortium of Northern Dutch companies that all see opportunities in deliveries with drones. Five parties have now signed the collaboration, and together with them, DDS expects to draw up a roadmap and start with the first test flights in 2023. This will focus on urgent and necessary products delivered to established fixed points. All of the consortium partners see drone deliveries adding value to their current business-models, specifically with regard to:

- faster delivery
- more efficient and sustainable deliveries
- decrease of stock value due to fast (JIT) delivery
- lower personnel costs due to less fragmentation of labour. For example, quick and efficient delivery services will allow the centralisation of specific activities, e.g. analysis of blood samples.

For the coming years the company see a potential market where the higher costs of fast and efficient deliveries is justified by the added value of the service and/or the high opportunity cost of using the next best alternative.

5 The Future Potential for Drone Delivery

Before examining the future potential for drone deliveries based on the experiences in Scotland and the Netherlands, it should be stressed that the technology, and more exactly, the employment of that technology in operations is at a very early stage of development, so what is presented in this section are purely initial thoughts based on what is known today. These take the form of possible scenarios, and where possible, were developed with a hierarchical perspective, hence in many senses are cumulative. Also listed are the potential constraints that were identified at the scenario development stage.

5.1 Scenario 1: Specialised Delivery

Under this scenario, drones will only be used for deliveries of specialised high value items, the clear examples being medical supplies or urgent industrial parts. As such, this would be restricted to business-to-business (B-2-B) services. Most likely to be employed where there are short sea crossings (islands) or in remote areas where this would be the single collection/delivery, i.e. low route densities/drop sizes.

Potential constraints: air regulations (administration processes and remotely controlled flight), difficulties in co-ordination?

5.1.1 Evaluation: Scenario 1

All key informants and focus group participants agreed that Scenario 1 is highly likely, and in many senses this is where operations are almost at now. All agreed that the demand for such services could be met by the underlying economics of operation. Key informants however did highlight the points given above in Section 3.2 with regard to regulatory change. Nevertheless, there is sufficient evidence coming out of current on ground developments that this is a realistic possibility for future deliveries by drones. The only constraints are restrictions concerning air space and integration with current logistic operations. As a consequence, progress towards this scenario will not occur overnight and ‘as the norm’ may still be some way away.

5.2 Scenario 2: Premium deliveries, same day/instant

Under Scenario 2, drones would be used to provide same day or instant deliveries (defined by Dablanc et al, 2017 as within 2 hours of order placement) at premium rates, hence would include business to customer (B-2-C) services. Lee et al (2016) highlight that around 20% of Amazon's e-commerce meet the criteria for same day delivery. Basic airline economics however would suggest utilisation is vital, hence drones would need to be kept in the air for as long as possible and service as many clients as possible. This inevitably means short distances, light packages and services restricted to urban areas.

Potential constraints: air regulations (flying over mass populations), public acceptance/intrusion, underlying economics of operation.

5.2.1 Evaluation

As regards Scenario 2, technical key informants were less committal. In some senses, this may reflect their area of expertise, which lies outside of logistics. Within the focus group however, this scenario was initially viewed as a commercial extension of scenario 1, and hence by implication may suggest this is a possible future development. Questions were raised however over two key areas. Firstly, the demand for such services and the charges levied, as in the latter case these would have to at a rate to avoid demand outstripping supply otherwise the service would become redundant; after considerable discussions participants agreed that delivery charges would need to be set at almost prohibitive (rather than premium) rates in order for this to be a realistic possibility. This in some respects ties in with the earlier cited work of Joerss et al (2016), who to repeat found that only 2% of respondents were willing to pay significant premium rates for instant deliveries by drone. As such, this scenario may still be viewed as a possibility. A second concern however was raised with regards to public/social acceptability, with particular reference to not only the visual intrusion of public space, but also the noise created by current operational drones (issues that re-emerged under Scenario 4). Whilst these factors may be partly overcome in the future, focus group participants agreed that this would suggest that Scenario 2 may only have limited applications, be subject to future regulatory constraints and would only be feasible at prohibitive rather than premium rates. Given these difficulties, then outside of rural areas or areas of very light population density, this scenario seems unlikely.

5.3 Scenario 3: Milk run outliers

In this scenario, drones are used as part of the normal last mile delivery service, hence again includes B-2-C services, but are employed on the basis of cost savings of delivery rather than the consumer's willingness to pay (as in Scenario 2). In other words, to deliver milk run outliers. The basic scenario is that consignments would arrive at a regional distribution centre, and delivery runs then optimised using a combination of vans and drones. Drones would therefore be employed for out of the way one off deliveries, and hence the strong implication is that this is most likely to be in rural areas or locations with clear geographical barriers.

Potential constraints: air regulations (integrated airspace), staffing? Is it worth optimising milk runs on this basis? How far does an outlier need to be to make this viable?

5.3.1 Evaluation

In the course of evaluating Scenario 3, it emerged that this becomes more problematic, as to some extent this again leads back into regulatory issues, hence in terms of the views of technical key informants, these are outlined under Scenario 4. As regards the focus group, an early issue emerged with regards to the extent to which drones could be used in addition to standard delivery vans, and two possibilities emerged. In the first case, and self-explanatory, the two operate entirely independently. In the second case, in the rural context the low route density associated with drones could be considerably improved if the drone could be serviced along its flight path by a ground based delivery van, i.e. the two operate in unison. In some senses therefore, these represent two different variants of the scenario, 3a independent operation and 3b unison operation. Taking 3b first, questions were raised with regards to the level of automation required for this to be a realistic possibility, in many senses therefore this followed on from key informant discussions, and it was accepted that in the first instance, in order to be feasible this would require major regulatory change. This then led into discussions around 3a, where focus group participants did see some potential for such operations, with one in particular actively engaged in piloting the use of drones in rural areas in combination with smart lockers. However, during the discussions the diversity of 'rural' areas was also highlighted, and hence the feasibility of drone use under both scenario 3a and 3b would appear to be very much dependent upon the geography of the area, with the general view being that such applications may be limited to unique rural conditions or isolated locations, and hence employment in this context more likely to be limited rather than on a wide scale basis.

5.4 Scenario 4: Mass Delivery

Scenario 4 represents mass employment of drones in last mile logistics. This includes B-2-B and B-2-C services and as such drones are a fully integrated part of supply chain systems. Orders/packages will be small in nature and allow for same day delivery. Services will operate in both urban and rural areas, in the case of the former where travel distances are relatively shorter, in the case of the latter this will general encapsulate Scenario 3. All operations will be supported by considerable infrastructure at logistics hubs. In terms of 'mass' delivery, from the very few estimates that exist, this would represent around 25-35% of all deliveries.

Possible constraints: Basic drone economics, the need for multi piloting and increased automation, air regulations (continually flying over mass populations), general social acceptability.

5.4.1 Evaluation

When it comes to Scenario 4, technical key informants without exception were almost completely unresponsive to this potential development. No clear reason emerged for this, but the very strong implication is that in many senses this scenario is out with the terms of reference of current knowledge. What it represents therefore is a situation that simply cannot be contemplated/evaluated from today's perspective. In the discussions however, it became evident that for this scenario to represent a realistic future outcome, there needs to be significant change, both in the state of technology and in the regulatory framework under which commercial drones operate. It is in the latter case where the real unknowns lie, with the big issues centring on the integration of commercial drones into unified (and urban) airspace and the required step change from essentially human controlled ATC systems to partially or fully automated ones.

In the course of the focus group however it became clear that from a purely logistical perspective, this scenario also seems unlikely. In the first instance, the focus group recognised that, as highlighted above, drones perform poorly with reference to route density and drop size. In order to overcome these limitations, this would need a significant improvement in the underlying economics of operation. The focus group also highlighted there may also be limitations with regard to the available airspace within which 'mass' deliveries could take place, on which point the discussion led back to the issues raised under Scenario 2. Under this scenario however, given the considerable escalation of operations that this would entail, these barriers seemed even more extreme and without resolution. As such, Scenario 4 at this point would appear to be very unlikely.

6 Conclusions and Closing Comments

Probably the main conclusion coming out of this initial research with regards to the future potential for drone deliveries over the last mile was reflected in an early comment made by one of the key informants, who stated:

> *"The drone industry is all smokescreen and mirrors".*

Certainly our experience in the process of carrying out this research would strongly concur with that view, to which the term 'and a high degree of hype' could also be added. Nevertheless, the methodology employed has enabled a high degree of the smoke, mirror images and hype to be cleared and some valuable insights gained. The paper finds that much of what exists in the public domain and to an extent the academic literature considerably overstates the potential for future drone deliveries over the last mile. Major failings occur with regard to avoidance of regulatory issues/barriers and the realities of the underlying economics of drone operation. In terms of the latter, key is that drones perform poorly with regards to route density and drop size. Where the impact of these two factors can be nullified, then it is in these areas where considerable potential exists. In terms of the four scenarios developed in the course of this research, this would relate to Scenario 1 (specialised deliveries) and to a lesser extent Scenario 3a (piloted milk run outliers in rural areas). Of the other three (2 - premium deliveries, 3b – automated milk run outliers in rural areas, 4 – mass deliveries), major obstacles exist with regards to the regulatory framework and the economics of operation, and hence at this point in time, these appear to be either very limited or unlikely applications.

Far more research however is required in order to build up the evidence base, both in terms of academic knowledge and for the purposes of regulatory progression. Outside of operational issues, other key areas include the environmental impact with regards to noise levels and integration with the planning policy/framework, particularly with regards to urban mobility, public acceptability and policy led initiatives such as low emissions zones. Key to this is to be found in greater collaboration between the industry, regulatory authorities, logistics providers and the academic community.

7 References

Amazon (2022). Amazon Prime Air. Found at: https://www.aboutamazon.co.uk/news/innovation/prime-air, last accessed on 26th October 2022).

Bryman, A. (2001). *Social Research Methods*. Oxford: Oxford University Press.

Business Insider (2022). "Amazon will pay a whopping $63 per package for drone delivery in 2025 and it shows just how the company is still grappling with cost issues for last-mile delivery". Found at: https://www.businessinsider.com/amazon-prime-air-drone-delivery-cost-63-per-package-2025-2022-4?r=US&IR=T, last accessed on 19th December 2022).

Cowie, J. and Fisken, K. (2023). Cycle Logistics. In Ison et al (eds.), *The Routledge Handbook of Urban Freight*. Routledge: Aldershot.

Dablanc, L., Morganti, E., Arvidsson, N., Woxenius, J., Browne, M., & Saidi, N. (2017). The rise of on-demand 'Instant Deliveries' in European cities. *Supply Chain Forum*, 18(4), 203–217. https://doi.org/10.1080/16258312.2017.1375375 NOT CITED IN TEXT

DBEIS/DfT (2022). *Advancing airborne autonomy: commercial drones saving money and saving lives in the UK*. London: Department for Business, Energy and Industrial Strategy/Department for Transport.

Doole, M., Ellerbroek, J. and Hoekstra, J. (2020). Estimation of traffic density from drone-based delivery in very low level urban airspace. *Journal of Air Transport Management*, 88, 101862, DOI: 10.1016/j.jairtraman.2020.101862.

Figiozzi, M. (2017). Lifecycle modelling and assessment of unmanned aerial vehicles (drones CO_2e emissions. *Transportation Research Part D*, 57, pp. 251 – 261.

Goodchild, A. and Toy, J. (2018). Delivery by drone: an evaluation of unmanned aerial vehicle technology in reducing CO_2 emissions in the delivery service industry. *Transportation Research Part D*, 61, pp. 58 – 67.

Joerss, M., Schröder, J., Neuhaus, F., Klink, C., Mann, F., 2016. Parcel delivery: The future of last mile. Retrieved from McKinsey&Company: https://www.mckinsey. com/industries/travel-transport-and-logistics/our-insights/how-customer-demands-are-reshaping-last-mile-delivery.

Keeney, T., 2015. How can amazon charge $1 for drone delivery? Found at: https://ark-invest. com/research/drone-delivery-amazon, . (Last accessed 15th December 2022).

Kim. S. (2020). Choice model based analysis of consumer preference for drone delivery service. *Journal of Air Transport Management*, 84, 101785. DOI: 10.1016/j.jairtraman.2020.101785.

Lee, H. L., Chen, Y., Gillai, B., Rammohan, S., 2016. Technological Disruption and Innovation in Last-Mile Delivery. Retrieved from Stanford Graduate School of Business: https://www.gsb.stanford.edu/faculty-research/publications/technological-disruption-innovation-last-mile-delivery., last accessed on 19th December 2022).

PwC (2022). *Skies Without Limits v2.0: the potential to take the UK's economy to new heights*. London: PwC, and available at https://www.pwc.co.uk/intelligent-digital/drones/skies-without-limits-2022.pdf, last accessed 21st December 2022).

Stolaroff, J., C. Samaras, E. O'Neill, A. Lubers, A. Mitchell and D. Ceperley (2018). Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery. Nature Communcations. DOI: 10.1038/s41467-017-02411-5.

Yoo, W., E. Yub and J. Jung (2018). Drone delivery: Factors affecting the public's attitude and intention to adopt, *Telematics and Informatics*, 35, pp. 1687 – 1700.

US Postal Service, Office of Inspector General (2016). *Public Perception of Drone Delivery in the United States*. RARC-WP-17-001. Washington: US Postal Service.