Distributed Aviation

The economics of electric aviation and how it will lead to distributed aviation

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Distributed Aviation - a new economic model for electric aviation - ADS Group
Regional Air Mobility | SACD (nasa.gov)
Economics of Hydrocarbon v Electric Aviation

- Hydrocarbons 11,900Wh/Kg
- Engines require complex engineering = high maintenance costs
- Propulsive Efficiency only 80-85%, the rest is noise and heat
- Efficiency requires long ranges at altitude making aircraft large
- Large aircraft = large airports to process sufficient passengers to pay for the infrastructure
Economics of Hydrocarbon v **Electric Aviation**

- **Battery technology** is sufficient for eSTOL at 400nm, 19 pax, eVTOL 130nm 4 pax + Hybrid options
- **Electric motors** are 90% efficient
- **Electric motors** = lower capital, operating and maintenance costs
- **There are more small airfields** closer to pax origin/destination than large airports with great surface access
- **Todays regional and GA airports** will be tomorrows sub-regional hubs + future vertiports
The Rise of Distributed Aviation

XXX could access XX of the 249 airport pairs or XX% of the 8515 frequencies
Regional Jets/Turbo Props

Frequency Distribution vs Cumulative Frequency - Europe

Source: AVEO Advisory analysis, Schedules 2017

Sub-Regional Aviation Range

Cumulative Frequency

Max Aircraft Range
Sub-Regional Airline Opportunities - UK

Largest Weekly Frequency Offered Routes UK/Ireland (<400km Distance)

EVTOL Preferred

- **ABZ – LSI** – Perfect Business Route (Oil Route) offering very high fares ($191) and high frequency/demand

- **LHR-MAN, DUB-EDI, DUB-MAN, DUB-GLA, MAN-SOU** – obvious choice connecting large business and financial hubs within UK and Ireland (moderate fares ~$100 and very high frequency offer)

- **EVTOL Niche** - very high frequency/demand routes connecting islands (Jersey, Mann, Guernsey) with mainland. Very high frequency and demand but low fares ($53-$81)
Sub-Regional Airline Opportunities – The World

Sub-Regional Airline Opportunities – France Originating
- Nice Niche - Nice – Monaco only 115m
- operated 1,568 times weekly by Euro Copter (6/4 seater)
- Top Routes - Weekly Frequencies Offered

Sub-Regional Airline Opportunities – Asia Originating
- Macau – Hong Kong
- Only 43m, 280 times weekly on AW139
- Perfect niche for VTOL operations
- Top Routes - Weekly Frequencies Offered

Sub-Regional Airline Opportunities – Norway Originating
- Domestic high frequency Hub-Spoke routes i.e.
- OSL – TRD – 224m, 204 times weekly on 8738m
- Possible frequent VTOL operations
- Top Routes - Weekly Frequencies Offered

Sub-Regional Airline Opportunities – Sweden Originating
- Domestic high frequency routes i.e.
- BMA-VBY – 138m, 84 times weekly on A320
- Niche for frequent VTOL operations
- Top Routes - Weekly Frequencies Offered

Sub-Regional Airline Opportunities – Spain Originating
- Leisure services to neighbouring islands i.e.
- ACE-UPA - 125m, 217 times weekly on ATR 72s
- Possible frequent VTOL operations
- Top Routes - Weekly Frequencies Offered

Sub-Regional Airline Opportunities – Germany Originating
- One day business trips between financial centres
- i.e. FRA-MUC – 180m, 188 times weekly on A321s
- Niche for frequent VTOL operations
- Top Routes - Weekly Frequencies Offered
Demand Modelling for Distributed Aviation

Current methods, why they will not work and how to do it
Context

The challenge of modelling demand:

- Electric aviation is likely to take place at smaller airports where there have traditionally been no scheduled services.
- Thinner electric aviation routes are likely to be more sustainable increasing attractiveness to start up electric airlines.
- Lack of origin and destination data coupled with purpose of trip will slow the identification of new routes.
- Electric aviation traffic has the potential to induce new traffic in areas that have not had access to air travel.
- Early adopters are likely to increase demand beyond what would normally be expected.
Methodology

**Initial analysis**
Schedule data

**Traditional approach**
Quantification and sifting

**New approach**
Mobile phone data information

**Routes Identification**

**Recommendations**

- **US domestic OAG weekly schedules** (w/c 8th of July 2019 as an indication of a typical week.)
- **Market Assessment:**
  - Distance thresholds
    - <150km
    - 150km-250km
    - 250km-400km
    - 400km
  - Frequency/capacity – identification routes with highest frequencies weekly
  - Aircraft type – identification of routes operated with smaller regional aircraft
  - Fare analysis – identification of routes with highest fares.
  - Frequency vs Fares routes – identification of highest fare/frequency routes.
- **Market assessment** – understanding the travel patterns of the travelling public on a country basis that is ideal for sub regional aviation which electric aviation will enable.
- **Travel Volume Assessment** – potential customers who could be converted to electric aviation based on mobile phone data Business travellers, VFR, Remote workers, travelling salesman etc.
- **Independent market assessment** – surface traffic flows (or air -surface) between areas without air services to identify markets with concealed potential.
- **Catchment Analysis of identified OD sets** to assess the true origin and destination of travellers for the strongest routings
- **City Case Study.**
- **Matrix of routes** – analysis on:
  - Frequencies and capacity proposition for the new routes. Average fares proposal. Based on the above, a proposal of a/c specs (capacity, LFs).
Initial Analysis – Schedule Data

Methods and limitations
Methodology – Traditional Approach

1. Traditional approach will inform
   - Overall number of UK domestic routings.
   - Average sector length.
   - Average frequency and capacity offering within each sector length thresholds.
   - Top routes in terms of frequency and capacity offered, average fares, fares per mile.
   - Top routes within sector distance thresholds.
   - Aircraft types used.
   - Average fares and fares per mile offered.

2. This will help understand
   - Overall frequency, capacity and fares offering on all UK domestic routings.
   - Highest demand city pairs.
   - Highest revenue city pairs (fares).
   - Average fare per mile pattern.
   - Possible list of routes with further potential for advanced air mobility.

3. Market assessment will be an indication of
   - Additional air traffic demand for selected routes
   - Competition on routings already operated by traditional airlines.
   - Average fare per mile and one-way net fare for future advanced air mobility.
   - Possible market share and stimulation of traffic of future advanced air mobility.
Traditional Approach – Quantification and Sifting

- Traditional approach - analysis based on OAG UK domestic weekly schedules (w/c 8th of July 2019) as an indication of typical operations within the UK before the Covid-19 pandemic.
- 202 existing UK domestic routes (July 2019) were assessed. 170 are within a minimum distance threshold of 150km, 101 within 150km – 400km a preferred operating distance. Those routes have been further analysed and sifted based on several factors, such as:
  - Frequency offering
  - Fares offered (current and booked in advance)
  - Capacity offering
  - Aircraft type
The charts above are UK domestic routes distribution of frequencies by aircraft type (and seats). Routes up to 400km are largely operated by small regional aircraft with up to 90 seats (with an exception of E95s, however, there are few offerings).

The aircraft type used with the highest number of frequencies weekly on routes up to 400km is DH4, with an average number of 78 seats.

Further analysis focuses on top routes in terms of frequencies that are offered on aircraft with up to 90 seats and within a threshold of 400 km.
• Top 35 routes within 400km offer a minimum weekly frequency of 28 and max of 84. This gives on average between 7 and 21 frequencies a day on aircraft with up to 90 seats.
• Average one-way net fares (booked one week in advance – which is typical for business travellers and probably the best indication of fare booking patterns for future advance air mobility users) vary from £33 and £190 on all routings.
• On routings between 150km-400km and on aircraft up to 90 seats vary from £18 and £241.
• The weighted average of fares on the routings between 150km-400km on aircraft up to 90 seats is £79.
Among the city pairs identified for mobile data assessment 6 have scheduled air services to different airports within their metro areas.

The highest frequency routes are those with the highest average one-way net fare, varying from £123 on EDI-LHR to £119 on EDI-LCY. Those with lower frequencies (around 20 weekly) offer relatively high average one-way net fares between £106 on MAN-NWI and £90 on LBA-LHR.

All routes offer a high fare per mile vs frequencies offered and present an opportunity for possible advanced air mobility operations.

It is worth mentioning that all those routes are offered on large single-aisle aircraft which translates to a large offer of seats. This means there is a great opportunity there for high frequency advanced air mobility operations.

The weighted average fare per mile for all scheduled services in the UK in 2019 was circa **£0.42**, however to better understand the fares offered a different approach has been adopted.
Electric Aviation Demand Modelling

The New Approach to Data
New Approach – Mobile Data Demand Assessment

- Analytics platform deployed in Telco Data Centre
- GDPR Compliant
- ISO-27001 Compliant

Mobility Analytics Engine
- Processes peta bytes of raw data
- Turns data into insights on human mobility
- Aviation specific analytics employed

Deep Insights into Journey Patterns
- Trip Volume
- Travel Time
- Trip Purpose
- Mode of Transport
- Demographics
- Routes
New Approach – Mobile Data Demand Assessment

LAU1 with specific catchment around areas of interest

Year, month, season, week, day of week, part of day

Year, month, season, week, day of week, part of day

Average household income per week as proxy for disposable income and propensity to fly

- 1-day business traveler
- Multi-day business traveler
- Travelling salesman
- Visiting Friends and Relatives (VFR)
- Remote workers
- Other visitors
- Resident
- Boarder traveler/resident

<table>
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<th>Day Of Week</th>
<th>Part Of Day</th>
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New Approach – Mini Mobile Data Demand Assessment

• At the request of FFC we developed a mini demand assessment of potential routes in the UK based on mobile data to demonstrate the value of this data set to electric aviation demand modelling.
• Based on our insight into the challenges of forecasting demand we sought to identify 15 potential routes.
• Our data providers have access to data from 2019 but the challenge was to convert it into a small but meaningful assessment of 15 routes including routes currently serviced by hydrocarbon aviation.

- Straight line v driving distance ratio
- Door to door travel time ratio
- Including 30min passenger processing times
- Drive times for cars and public transport are based on google analytics during typical peak hours
- Assuming 120mph airspeed
Routes Identification - Baseline

Manchester - Norwich

- Straight line distance: 158 miles
- Driving distance: 204 miles
- Travel time (cars): 244 minutes
- Travel time (public transport): 267 minutes
- Flight time* (advanced air mobility): 109 minutes

Flight time vs drive time (cars) ratio: 0.45
Flight time vs public transport ratio: 0.41
Straight line vs drive time distance ratio: 0.77

* Flight speed of 120mph + 30min for take-off/landing and boarding/de-boarding
## Routes Identification

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance (m) (driving)</th>
<th>Distance (m) (straight line)</th>
<th>Travel time (min) (cars)</th>
<th>Travel time (min) (public transport)</th>
<th>Flight time (min) (advanced air mobility)</th>
<th>Population combined (route)</th>
<th>Drive distance vs straight line ratio</th>
<th>Flight time vs cars ratio</th>
<th>Flight time vs public transport ratio</th>
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<td>302</td>
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<td>154</td>
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<td>169/172</td>
<td>190/201</td>
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<td>12880934/10979067</td>
<td>0.87</td>
<td>0.60</td>
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</tbody>
</table>
Routes Identification – Stimulation Curve

- To assess any future passenger market stimulation for advanced air mobility operations we have used the XXX stimulation curve. It is a commonly used and well adopted approach for new markets and new entrants on existing markets. The curve shows a correlation between the total traffic flows between two markets before and after new services are introduced.

- The stimulation curve was designed for air traffic to compare indirect traffic flows and the level of stimulation when a direct service is introduced, therefore it is a good, high level indication of stimulation for this exercise.

\[ y = -0.491 \ln(x) + 6.8124 \]
\[ R^2 = 0.9906 \]
• Other independent market stimulation analysis indicate higher stimulation impacts can be found for regional routes with small initial market sizes compared to XXXX stimulation curve.

• Routes with small existing demand shouldn’t be ignored from the beginning as the air travel demand may increase substantially due to new travelers as well as a shift from other modes of transport.

• For this exercise, the XXXX stimulation curve has been used to reflect a conservative approach.
On the 15 selected routes, 6 of them have scheduled airline services.

There are multiple airports within each metro area that offer direct air connections on those 6 routes (mainly from/to London).

Mobile data also include air traffic data therefore, one would suspect that mobile data would be higher than air traffic data, however the mobile data traffic in this exercise include only metro areas of the selected city pairs and immediate catchments, hence not all travellers are included. (i.e., for London, only the city of London and the neighbouring boroughs are included, therefore if there is a traveller commencing their journey in Woking and travelling to LHR to get a flight to Edinburgh they are not included in the mobile dataset, however they are included in the air traffic dataset).
The most popular mode of transport between the selected cities is private cars and public transport (trains).

Air travel prevails only on two routes, GLA-LHR and EDI-LHR, mostly due to long distances and very long travel time by surface transport.

Interestingly, for routes such as Birmingham – xxxx or Nottingham – xxxx the only mode of transport is private cars (circa 95% for both). Other modes of surface transport are marginal (mainly due to availability). This creates a great opportunity for advanced air mobility to gain a significant market share.
For the top 5 routes with the largest share of surface transport (cars) as the main mode of transport, our flight time ratio vs drive time ratio is one of the lowest and varies from .45 to .59.

That means those areas are very hard and time consuming to get to, therefore more car users would theoretically be able to switch to advance air mobility vehicles, with some significant time and economic gains.

For those areas (city pairs) where public transport is widely available (such as Edinburgh and London) the ratio of flight time vs public transport time is still very attractive for flight options.
When it comes to trip purposes on the selected 15 routes, on those where home or work related, the most popular trip purpose was business travel.

Between 25% (London- xxx) to 71.7% (Edinburgh – London) of all trips (that are work or home related) are trips for business meetings.

A significant number of trips taken between the selected 15 routes are work-home trips. On average, around 21% of all trips on those routes are commuter routes, and 35% are either VFR, leisure or other activities.
**Routes Identification - Possible AAM Operations**

| Route/Seats on Board           | Current weekly air demand (based on July 2019 schedules with a conservative LF of 65% assumed) | Mobile Data traffic flows (weekly) | Assumed stimulation of mobility (based on stimulation curve) | Total Mobile Demand after stimulation | Assumed market share % | Total Demand available for AAM | Assumed Load Factor | Frequencies per day required to meet the demand - Assuming a 4-seater (both ways) | Frequencies per day required to meet the demand - Assuming a 6-seater (both ways) | Frequencies per day required to meet the demand - Assuming a 9-seater (both ways) | Frequencies per day required to meet the demand - Assuming a 12-seater (both ways) | Frequencies per day required to meet the demand - Assuming a 19-seater (both ways) |
|-------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------|-------------------------------------------------------------|--------------------------------------|------------------------|--------------------------|------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Manchester/Liverpool–Norwich  | 481                                                                                             | xxxx                              | xxx                                                          | 19,440                               | 0.05                   | 996                      | 90%                    | 32                                                                              | 21                                                                              | 14                                                                              | 11                                                                              | 7                                                                              |                                                                                   |

- With stimulation of xxx and a 5% market share advanced air mobility vehicles could operate from 7 to 32 flights a day between Manchester and Norwich.

- Average fares on those routes could vary from £72–£106 one way.

- Using our R2 factor for fares modelling, advance air mobility on the Manchester – Norwich route could achieve an average one-way net fare of £110.
### Routes Identification - Possible AAM Operations

<table>
<thead>
<tr>
<th>Route/Seats on Board</th>
<th>Current weekly air demand (based on July 2019 schedules with a conservative LF of 65% assumed)</th>
<th>Mobile Data traffic flows (weekly)</th>
<th>Assumed stimulation of mobility (based on stimulation curve)</th>
<th>Total Mobile Demand after stimulation</th>
<th>Assumed market share %</th>
<th>Total Demand available for AAM</th>
<th>Assumed Load Factor</th>
<th>Frequencies per day required to meet the demand - Assuming a 6-seater (both ways)</th>
<th>Frequencies per day required to meet the demand - Assuming a 9-seater (both ways)</th>
<th>Frequencies per day required to meet the demand - Assuming a 12-seater (both ways)</th>
<th>Frequencies per day required to meet the demand - Assuming a 19-seater (both ways)</th>
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<td>996</td>
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<td>-</td>
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<td>-</td>
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<td></td>
<td>34,078</td>
<td>0.05</td>
<td>1,704</td>
<td>90%</td>
<td>55</td>
<td>37</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>Leeds/Bradford- xxx</td>
<td>-</td>
<td></td>
<td></td>
<td>16,497</td>
<td>0.05</td>
<td>825</td>
<td>90%</td>
<td>27</td>
<td>18</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Aberdeen- xxx</td>
<td>-</td>
<td></td>
<td></td>
<td>6,632</td>
<td>0.05</td>
<td>332</td>
<td>90%</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>2</td>
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</table>

Routes exceeding 240 km (150 m) – not suitable range-wise for a 4 seats eVTOL
Advanced Air Mobility Fare Estimation

- Using the PWC Sub Regional case adjusting for eVTOL and eCTOL we derive the following Average fare per mile and likely fares in comparison to existing fares.
- This indicates that the relative cost to users is likely to undercut the price for traditional aviation leading to a higher elasticity attracting more potential passengers than the case we have outline.
Comparable Fare Structure

Based on the review of business fares per mile the chart to the left outlines the approximate fares for the city pairs identified.

- On the lower end Peterborough – Leeds at £88 is comparable with a one-way rail fare of £91.
- On the higher end Nottingham - xxx at £137 represents value for money given the significant time savings achieved through flight.
- Based on a larger analysis and competitive pressure these fares are likely to be revised downward thus stimulating demand.
<table>
<thead>
<tr>
<th>The Big Numbers</th>
</tr>
</thead>
</table>
| **Time Savings**  
(over Road & Rail)  
13.6yr |
| **Economic Reclaim**  
(over Road & Rail)  
£4.3m |
| **Carbon Savings**  
(over Road & Rail)  
1.7m kg |
| **Levelling Up**  
(over Road & Rail)  
£1.1m economic reclaimer + 1m for SE connectivity |
| **Levelling Up**  
(over Road & Rail)  
£50.6m economic reclaimer + £46m for SE connectivity |
| **Northern Powerhouse** |
Many routes identified in the North of the UK  
Possible removal of £13m in Public Service Obligation flight funding |
| **Social Mobility** |
Significant increases in social mobility reducing economic inequality through the development of an accessible electric aviation network |
| **Airfield Protection** |
Identification of a network of secondary and general aviation airfields that have potential for commercial electric aviation services leading to tens of millions of pounds investment in infrastructure |