Distributed Aviation

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

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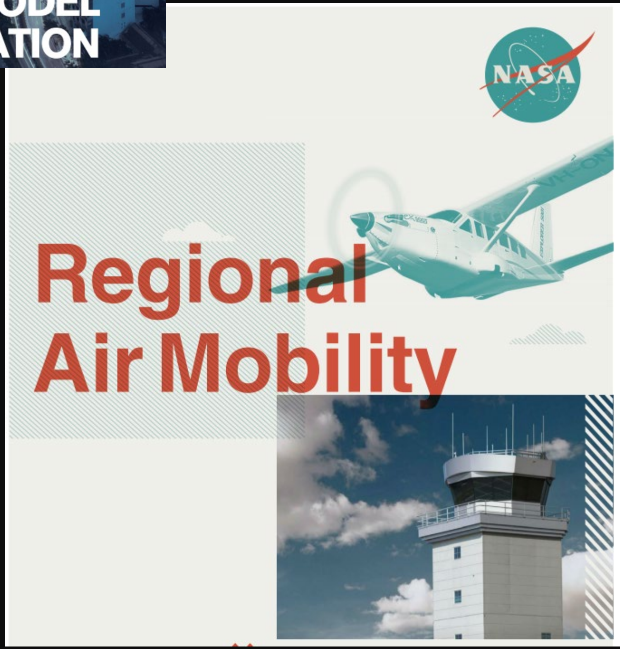
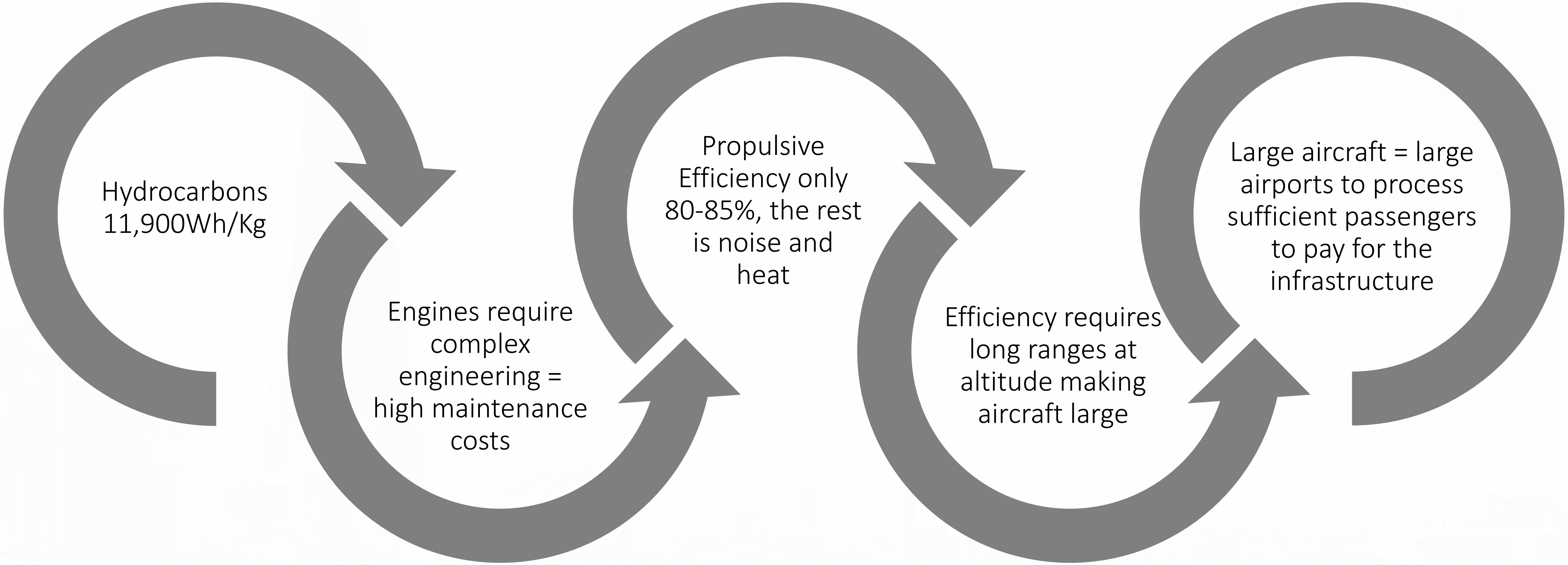
[Distributed Aviation - a new economic model for electric aviation - ADS Group]

[Regional Air Mobility | SACD (nasa.gov)]



Economics of Hydrocarbon v Electric Aviation



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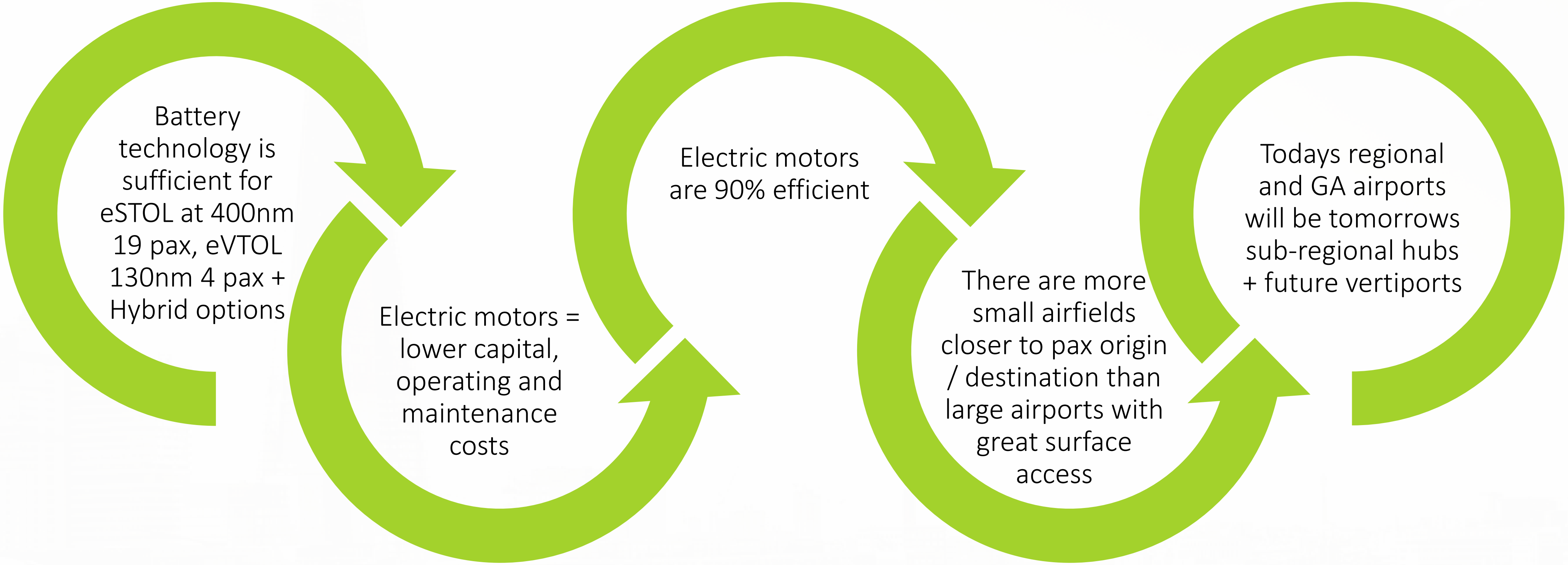
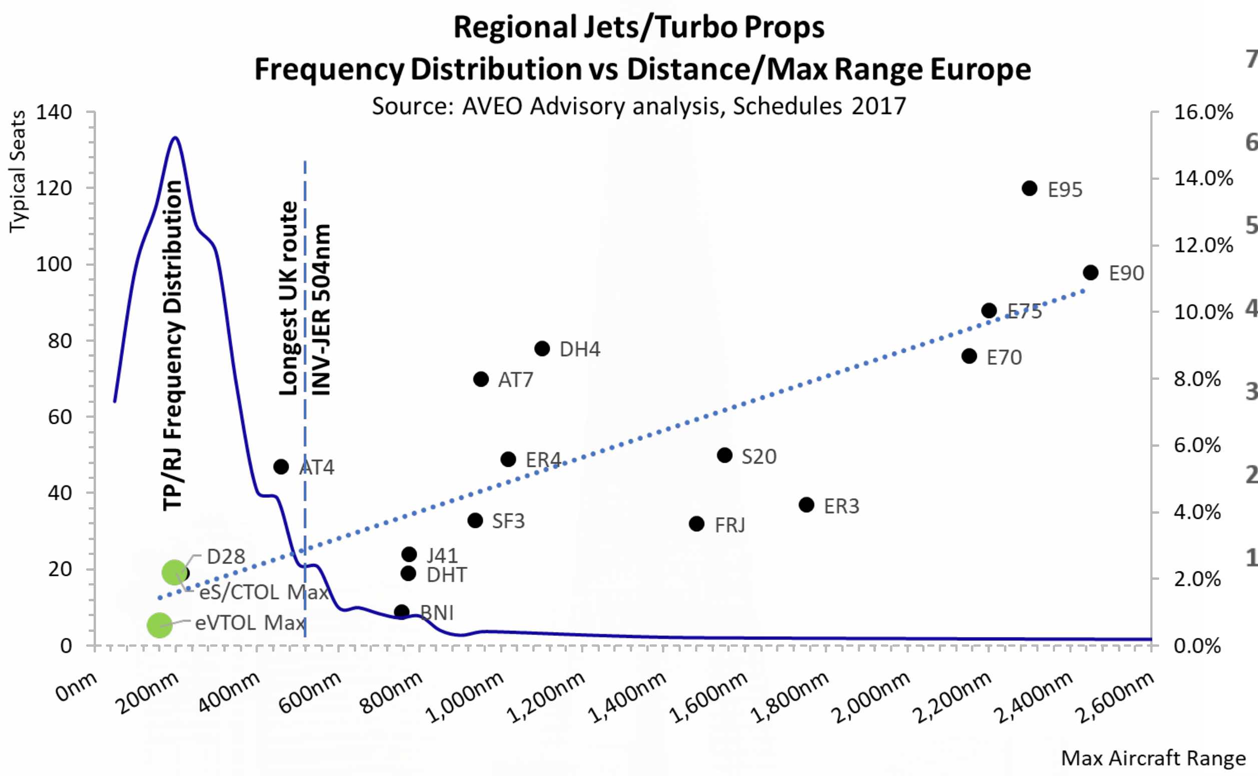
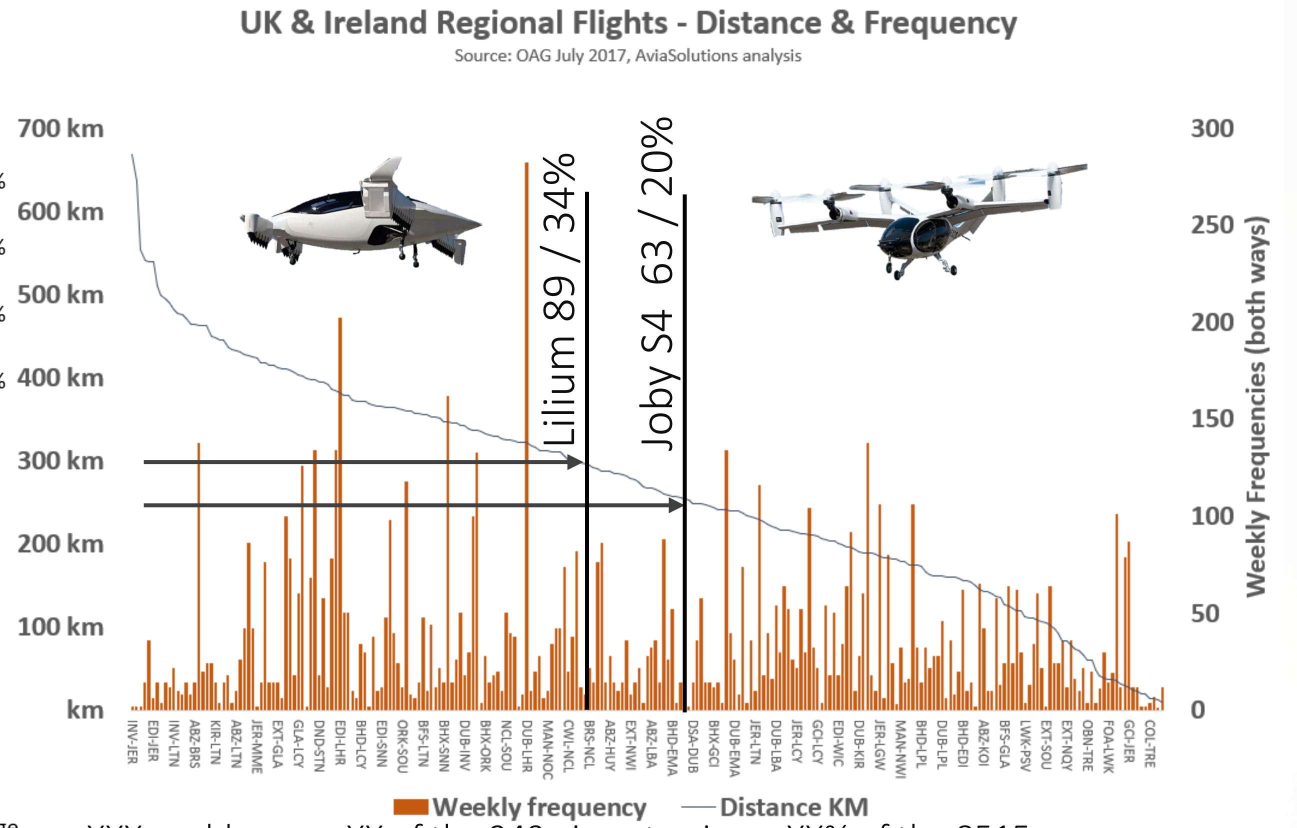


The Rise of Distributed Aviation

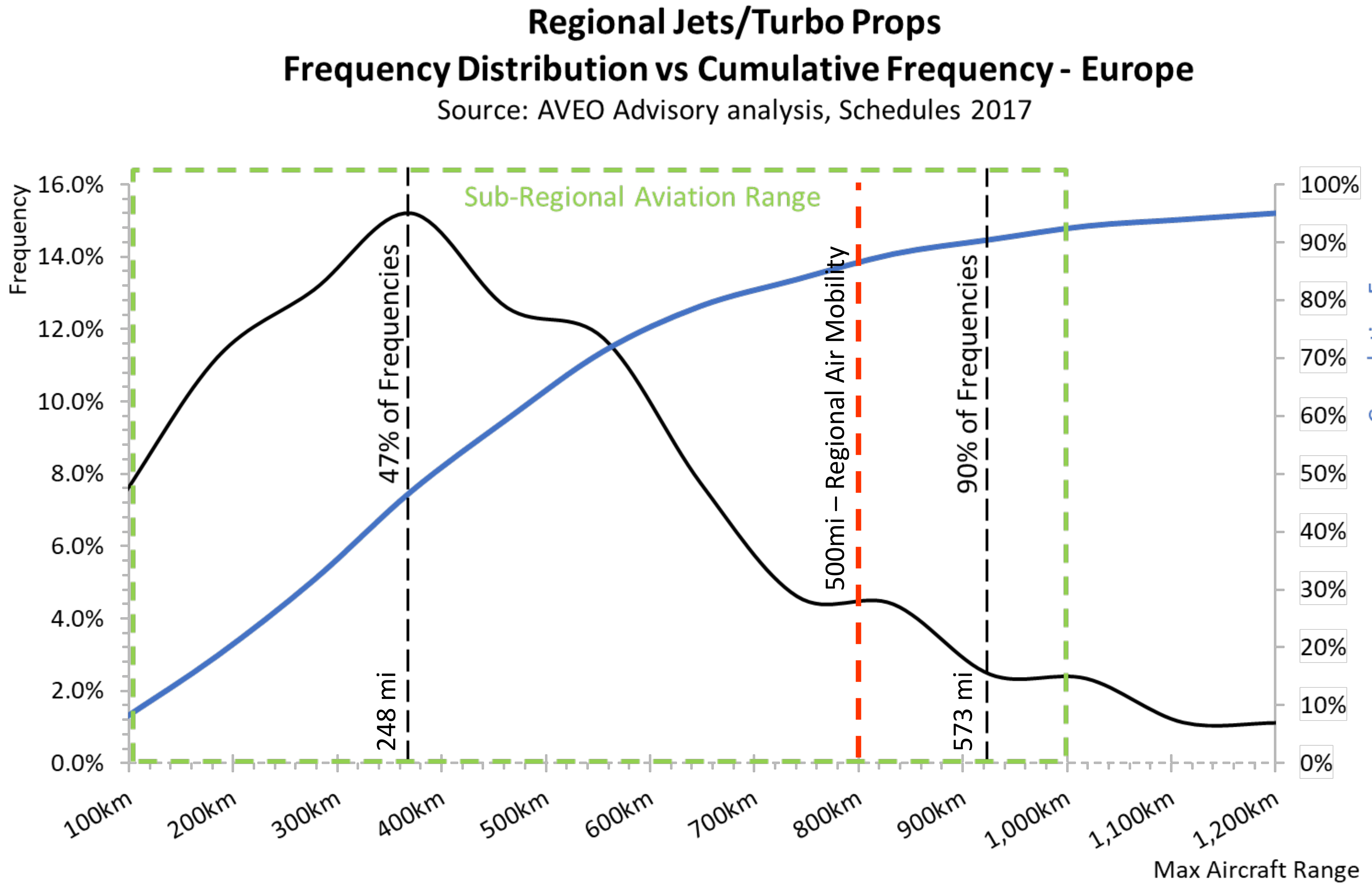




XXX could access XX of the 249 airport pairs or XX% of the 8515 frequencies

MagniX

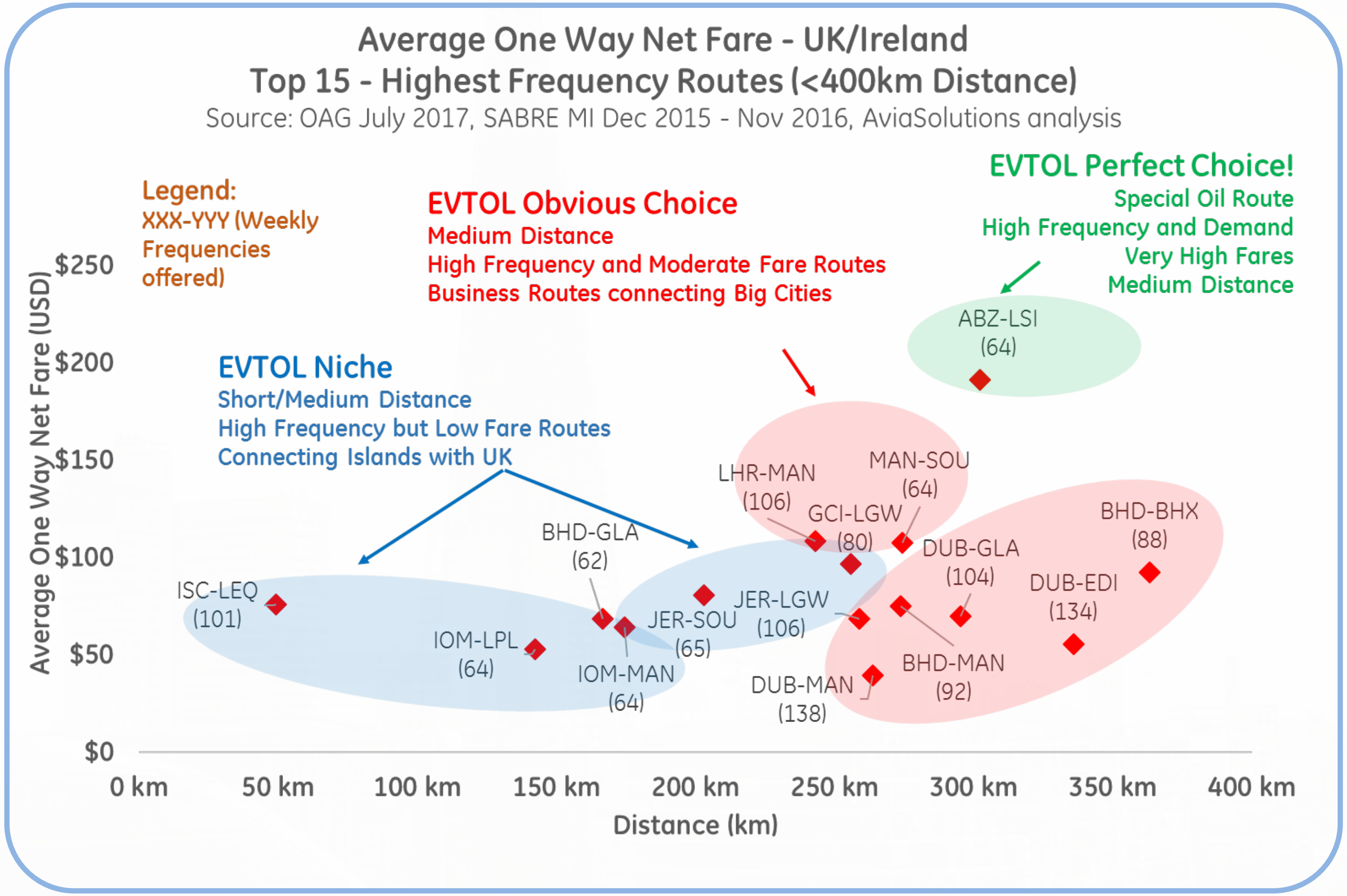
Heart Aerospace



Regional Jets/Turbo Props
Frequency Distribution vs Cumulative Frequency - Europe
Source: AVEO Advisory analysis, Schedules 2017
Frequency
16.0%
14.0%
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Sub-Regional Aviation Range
47% of Frequencies
248 mi
500mi – Regional Air Mobility
90% of Frequencies
573 mi
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Frequency
100km
200km
300km
400km
500km
600km
700km
800km
900km
1,000km
1,100km
1,200km
Max Aircraft Range

Sub-Regional Airline Opportunities - UK

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

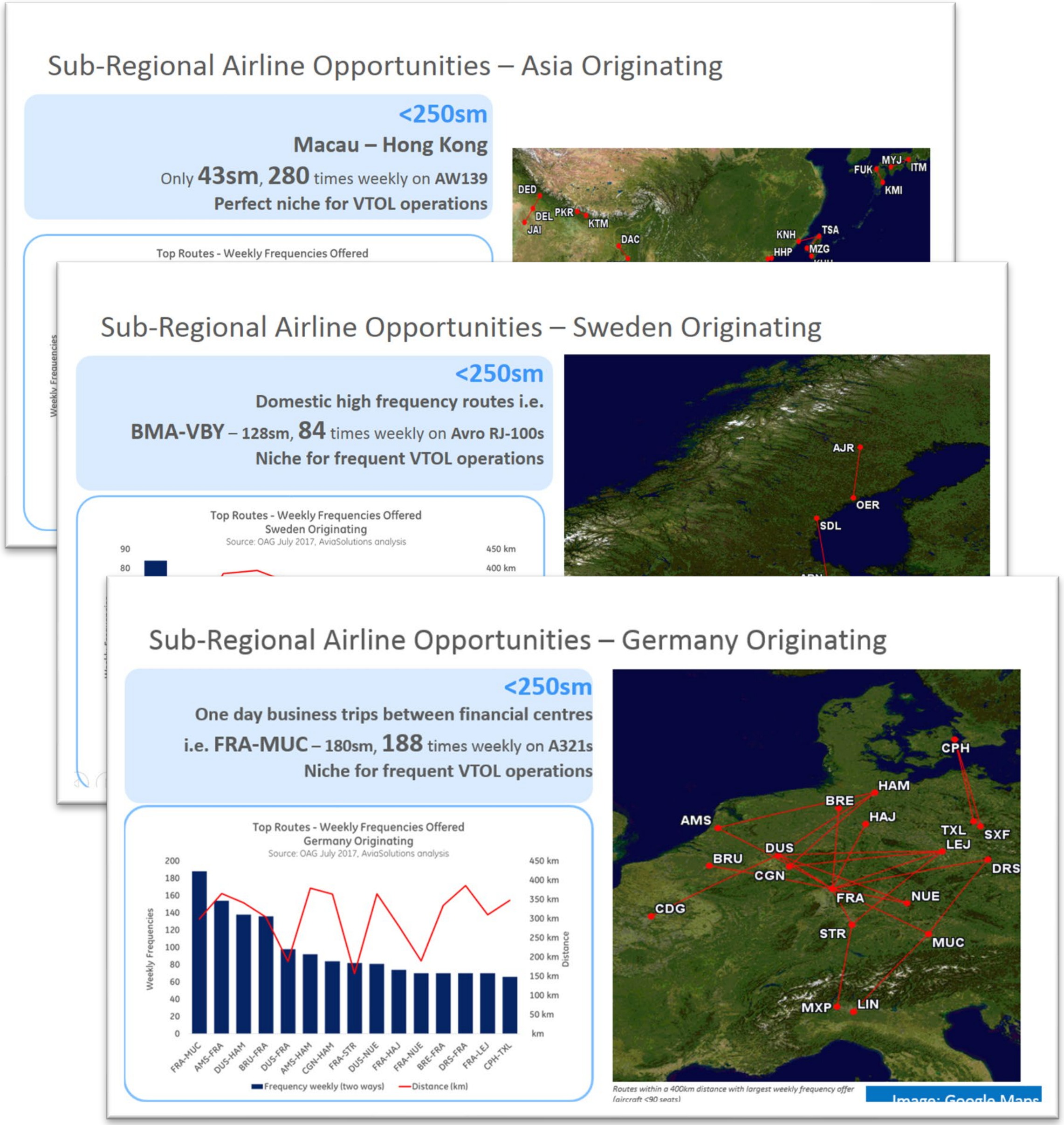


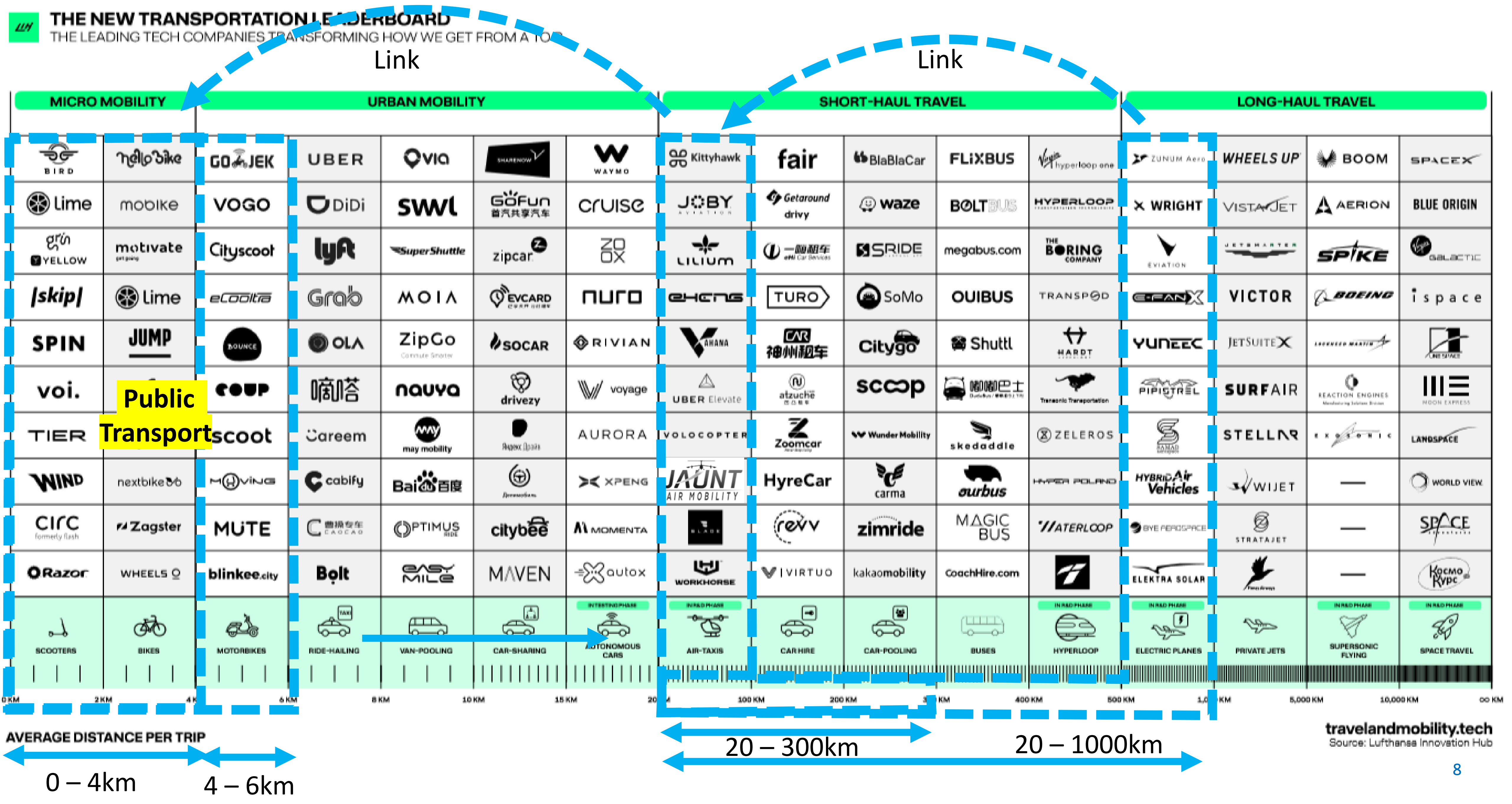
EVTOL Preferred

- **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**)

Routes within a 250sm (400km) distance with largest weekly frequency offer

Sub-Regional Airline Opportunities – The World




THE NEW TRANSPORTATION LEADERBOARD
THE LEADING TECH COMPANIES TRANSFORMING HOW WE GET FROM A TO B
Link
Link
MICRO MOBILITY
URBAN MOBILITY
SHORT-HAUL TRAVEL
LONG-HAUL TRAVEL
Public Transport
SCOOTERS
BIKES
MOTORBIKES
RIDE-HAILING
VAN-POOLING
CAR-SHARING
AUTONOMOUS CARS
AIR-TAXIS
CAR HIRE
CAR-POOLING
BUSES
HYPERLOOP
ELECTRIC PLANES
PRIVATE JETS
SUPERSONIC FLYING
SPACE TRAVEL
0 KM
2 KM
4 KM
6 KM
8 KM
10 KM
15 KM
20 KM
100 KM
200 KM
300 KM
400 KM
500 KM
1,000 KM
5,000 KM
10,000 KM
∞ KM
AVERAGE DISTANCE PER TRIP
0 – 4km
4 – 6km
20 – 300km
20 – 1000km
travelandmobility.tech
Source: Lufthansa Innovation Hub

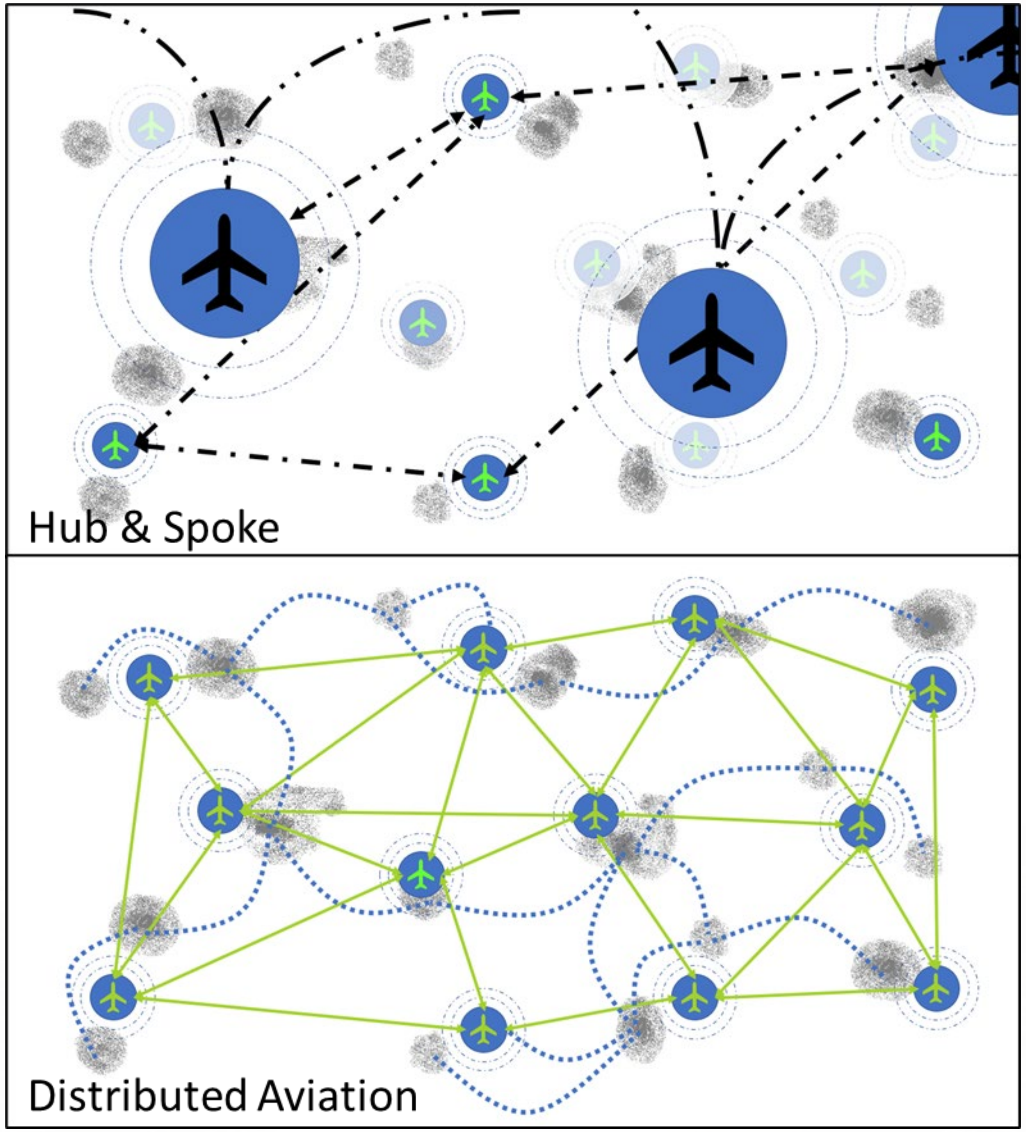
Demand Modelling for Distributed Aviation

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:

Secret Sauce

- 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

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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

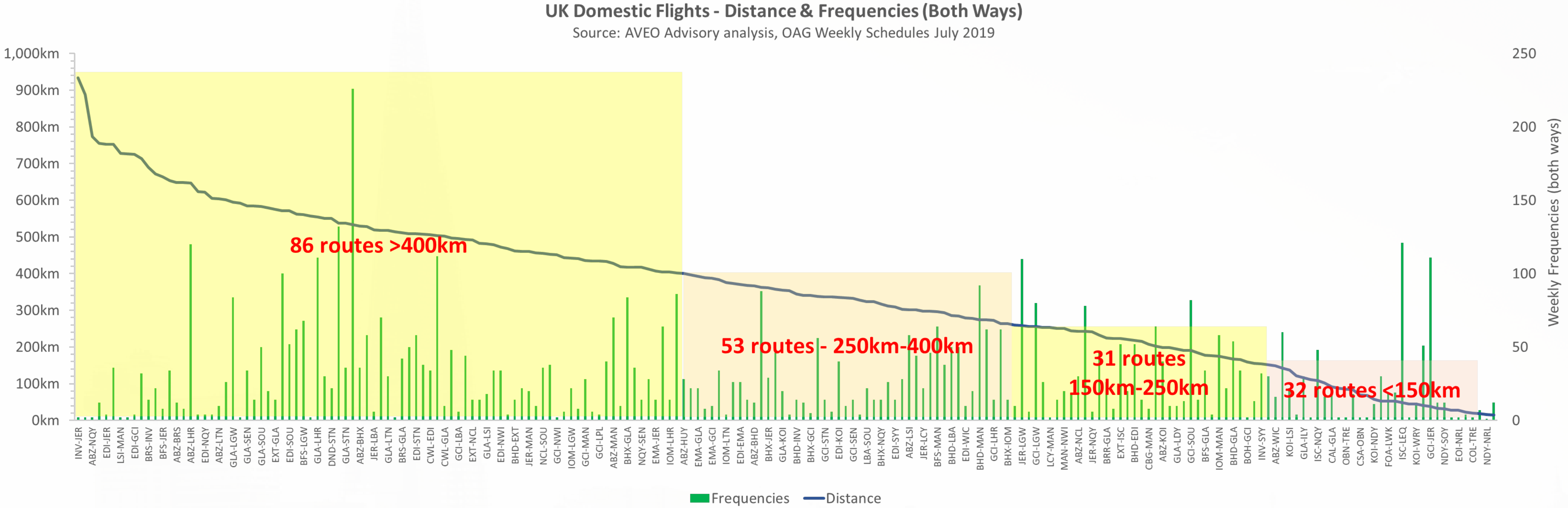
- Overall frequency, capacity and fares offering on all UK domestic routings.
- Highest demand city pairs.
- Highest revenue city pairs (fares).
- Average fare per mile pattern.
- Possible list of routes with further potential for advanced air mobility.

3

Market assessment will be an indication of

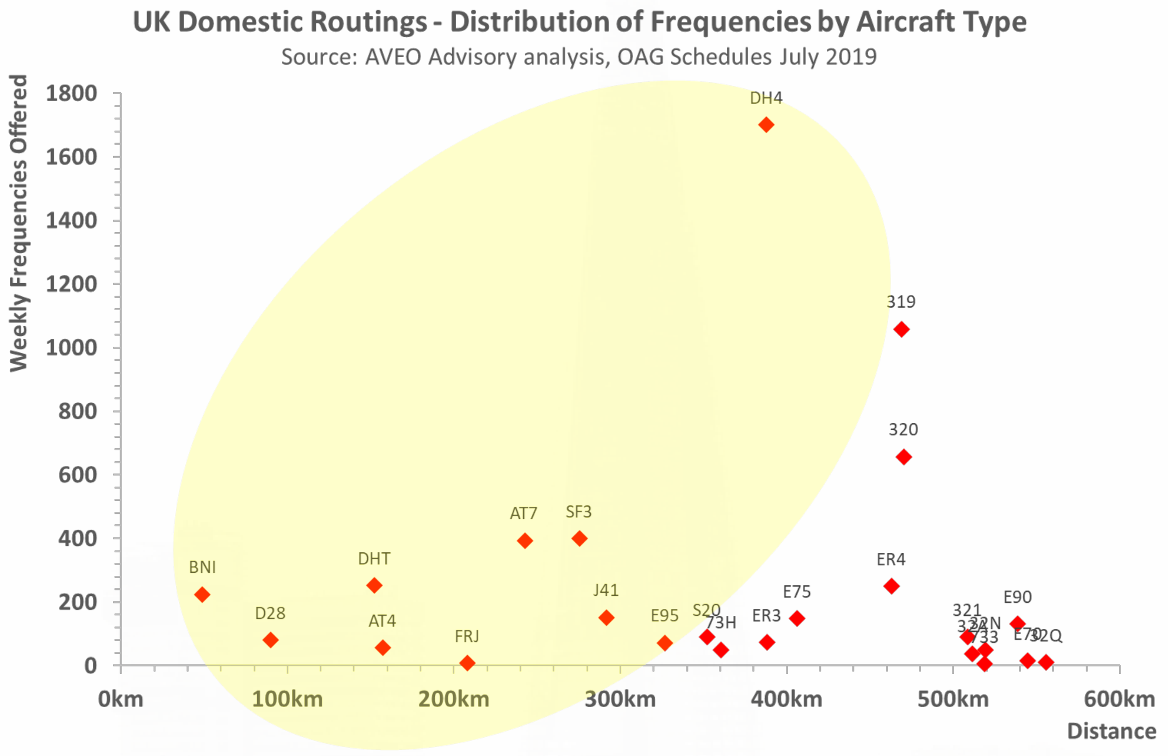
- Additional air traffic demand for selected routes
- Competition on routings already operated by traditional airlines.
- Average fare per mile and one-way net fare for future advanced air mobility.
- Possible market share and stimulation of traffic of future advanced air mobility.

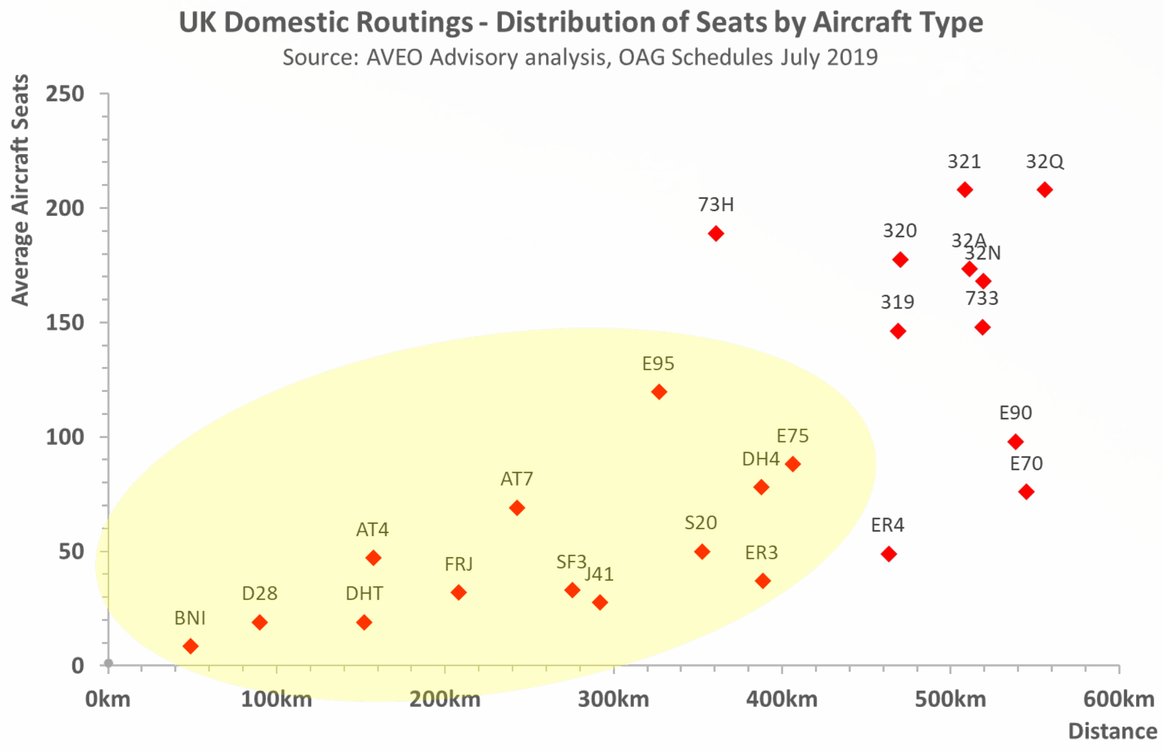
Traditional Approach – Quantification and Sifting



- 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

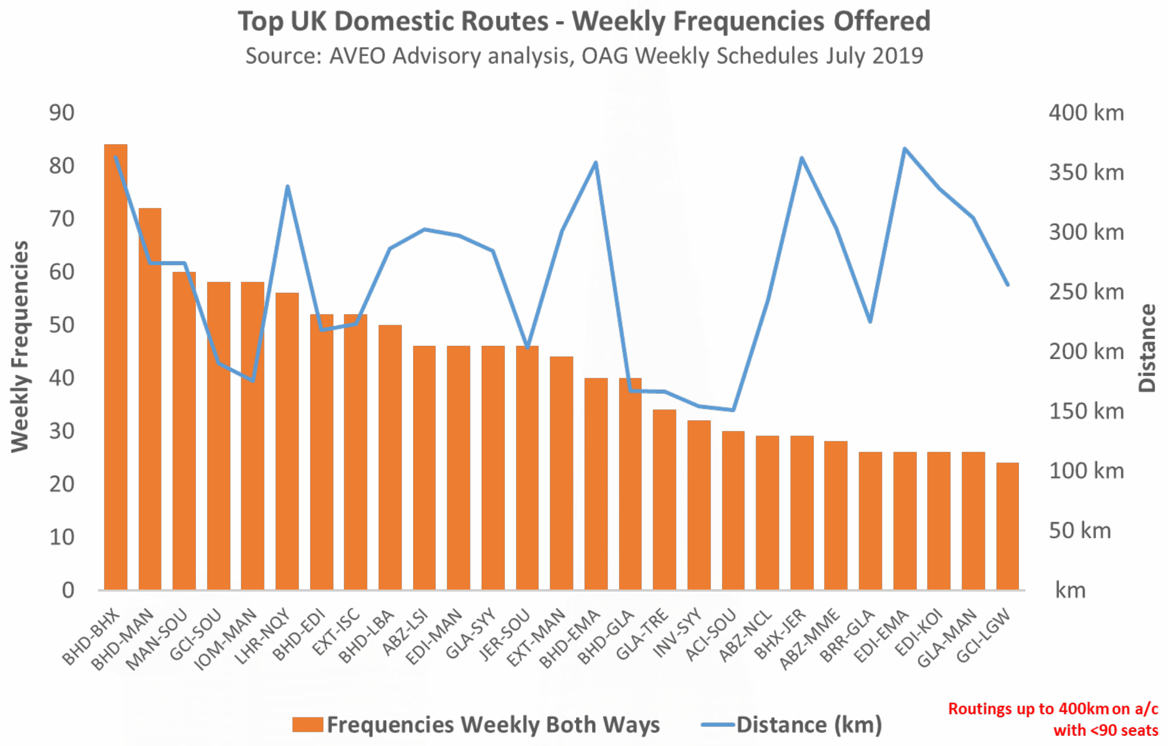
Traditional Approach – Quantification and Sifting

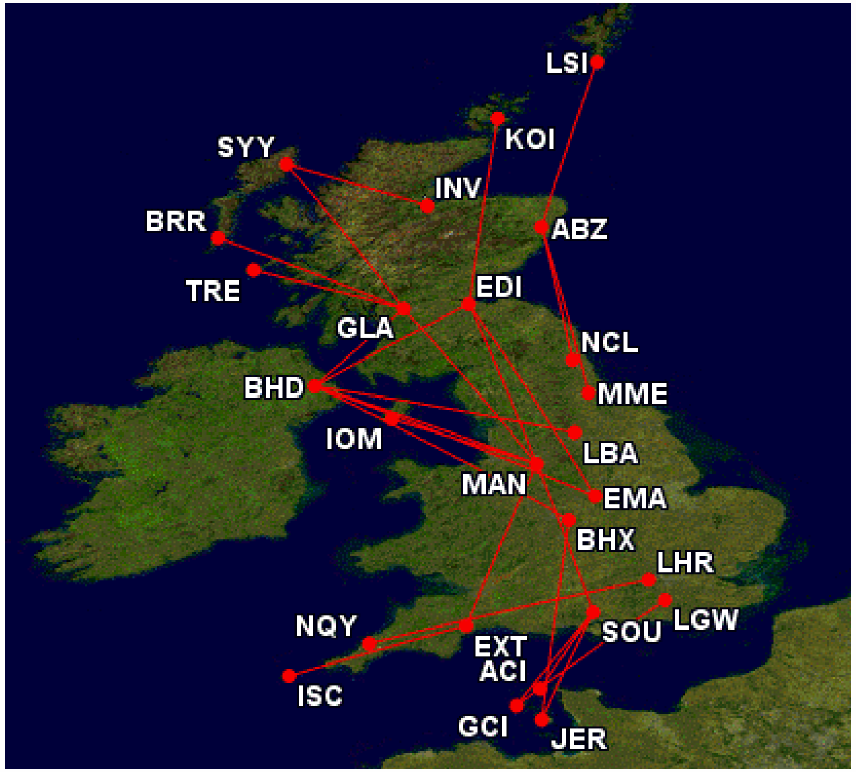




- The charts above are UK domestic routes distribution of frequencies by aircraft type (and seats). Routes up to 400km are largely operated by small regional aircraft with up to 90 seats (with an exception of E95s, however, there are few offerings).
- The aircraft type used with the highest number of 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.

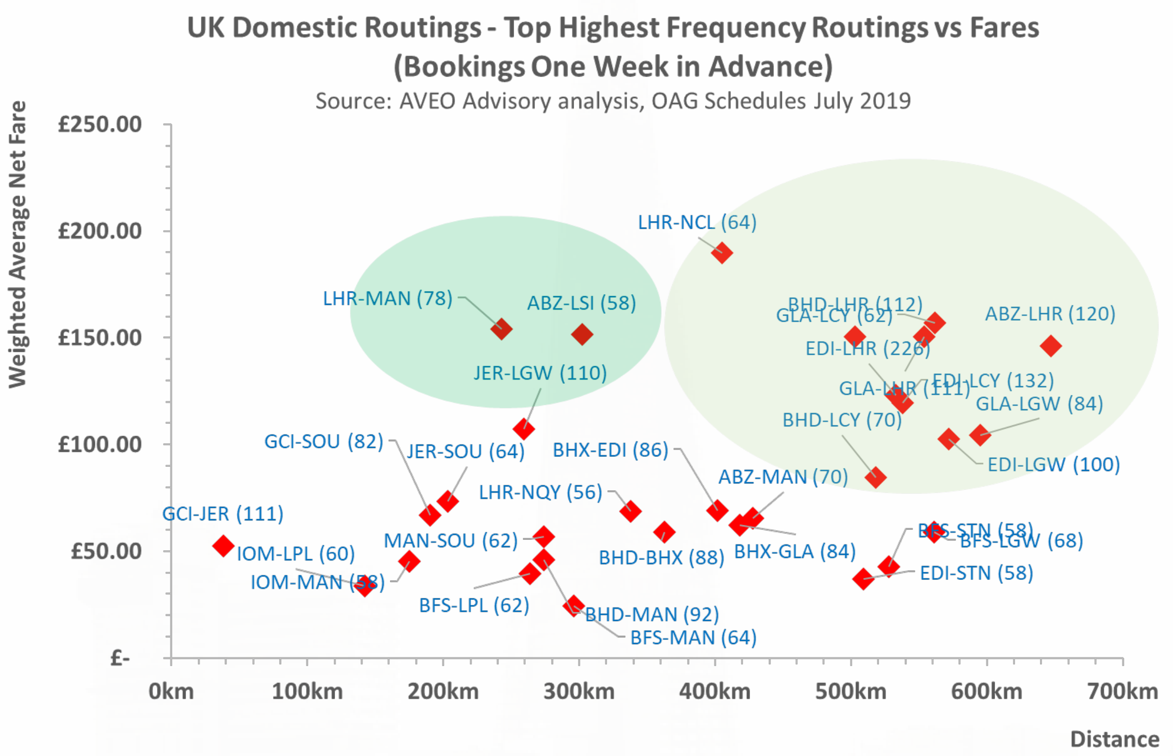
Traditional Approach – Quantification and Sifting

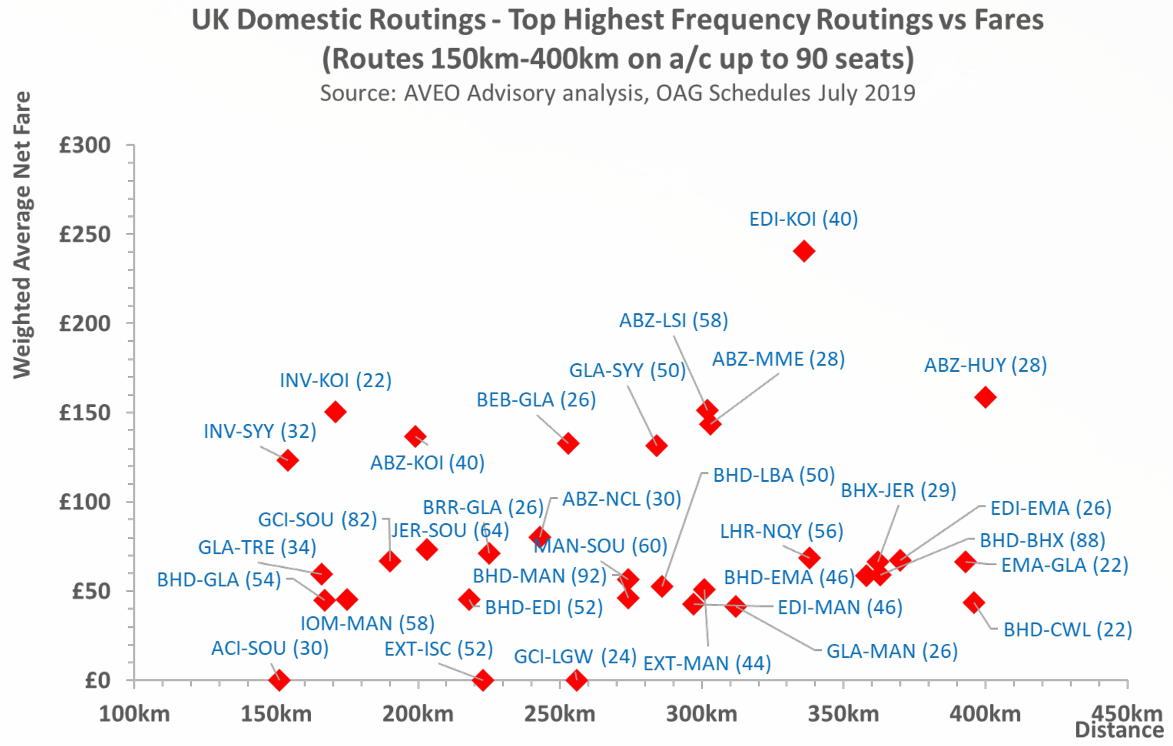




- Top 35 routes within 400km offer a minimum weekly frequency of 28 and max of 84. This gives on average between 7 and 21 frequencies a day on aircraft with up to 90 seats.

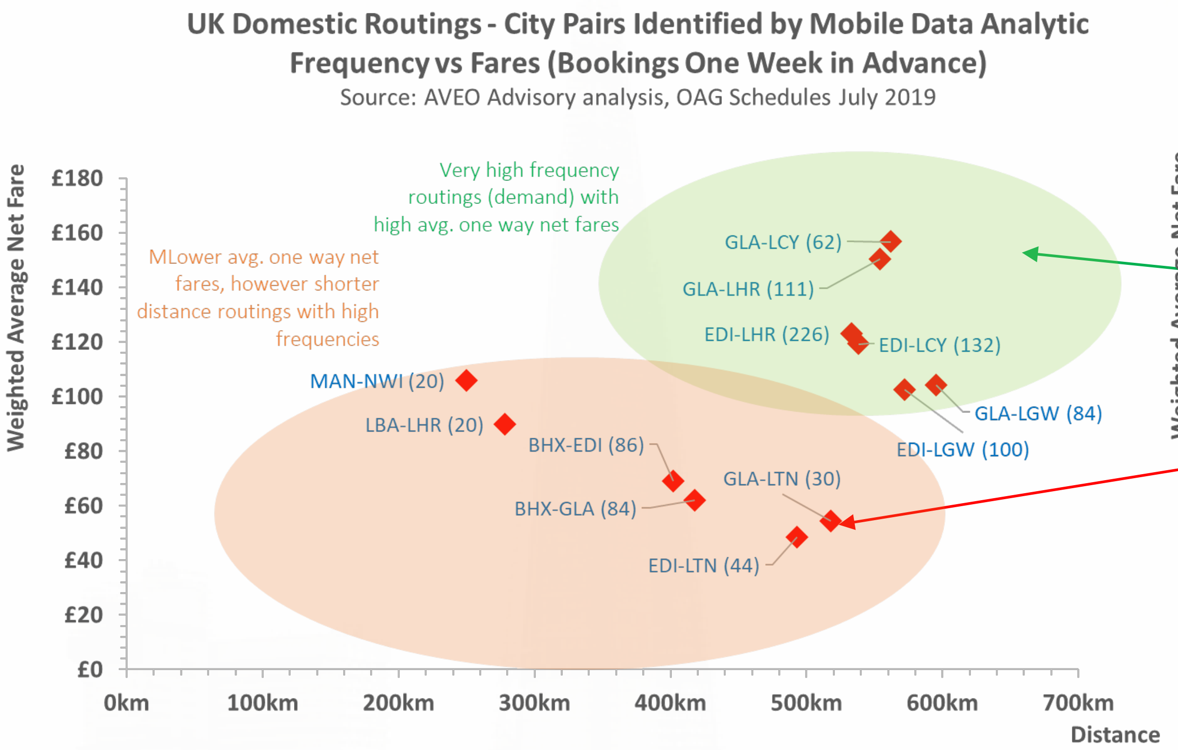
Traditional Approach – Quantification and Sifting

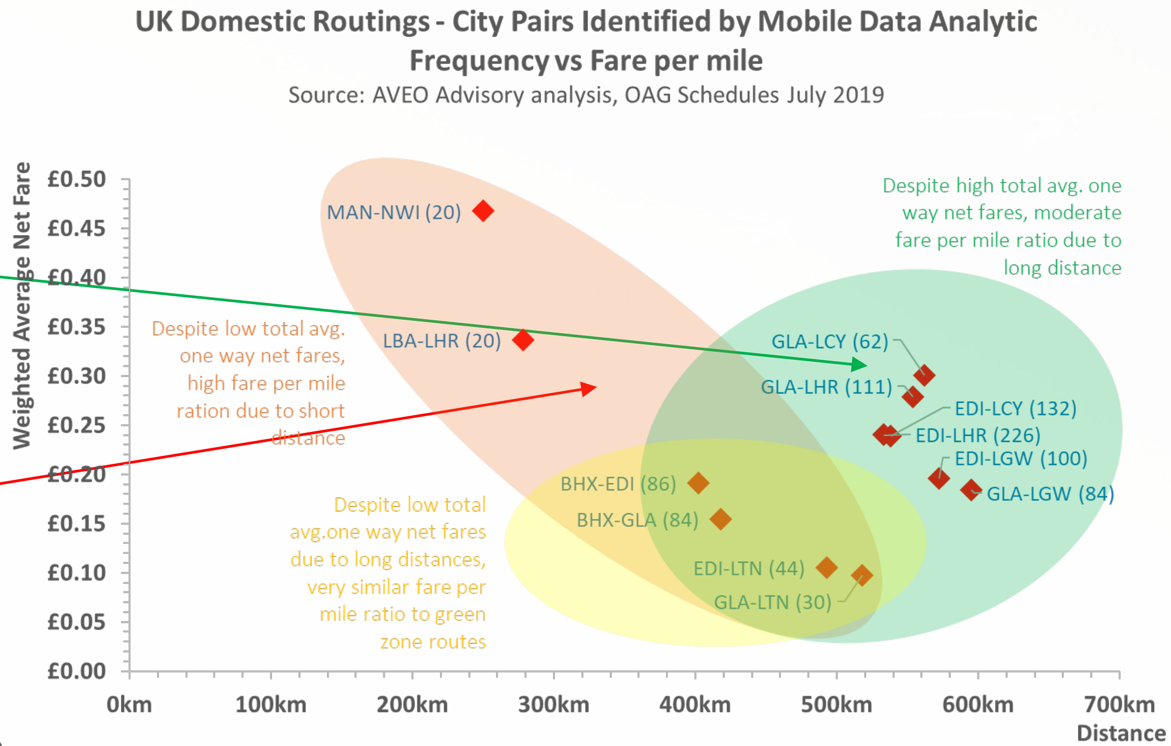




- Average one-way net fares (booked one week in advance – which is typical for business travellers and probably the best indication of fare booking patterns for future advance air mobility users) vary from **£33** and **£190 on all routings.**
- On routings between **150km-400km and on aircraft up to 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.**

Traditional Approach – Quantification and Sifting





- 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

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New Approach – Mobile Data Demand Assessment

Mobile Network Data

- 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

Spatial Resolution

LAU1 with specific catchment around areas of interest

Temporal Breakdown

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

Mode of Transport

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

Weekly Income

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

User Profile

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

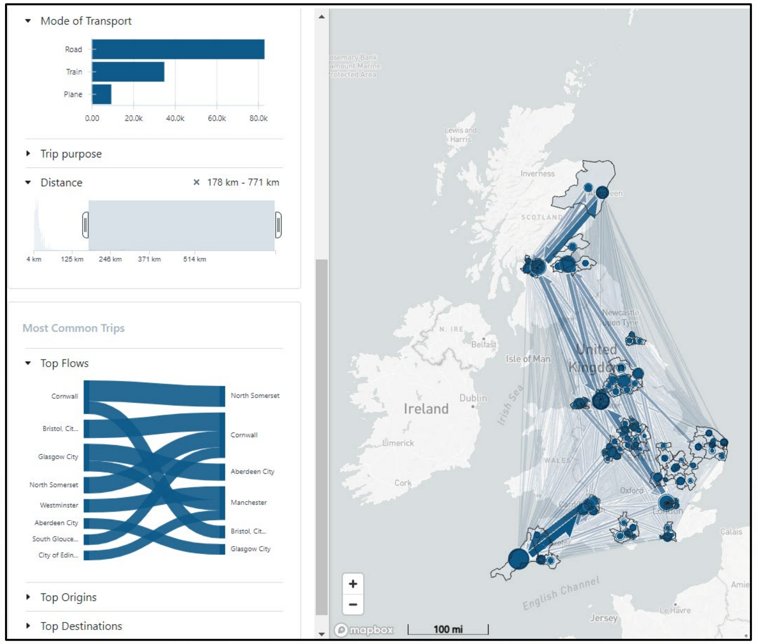
Started	Ended	Month	Day Of Week	Part Of Day	MoT	Demographic	Count
466935	579353	June	Monday	12PM-4PM	Plane	VFR	396
466935	579353	August	Tuesday	12PM-4PM	Train	Business Travel	667

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.

From this

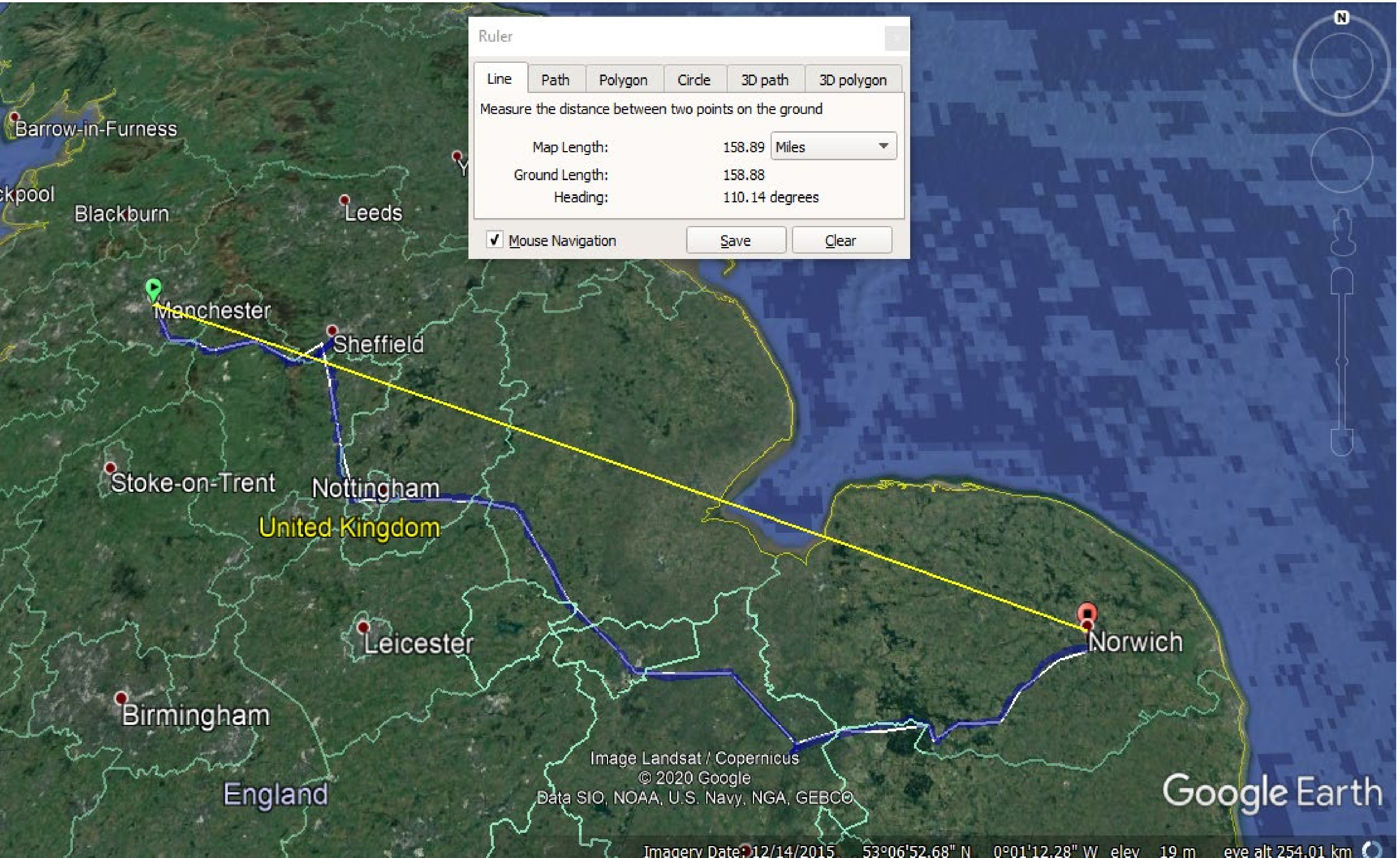
to this



based on this

- 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



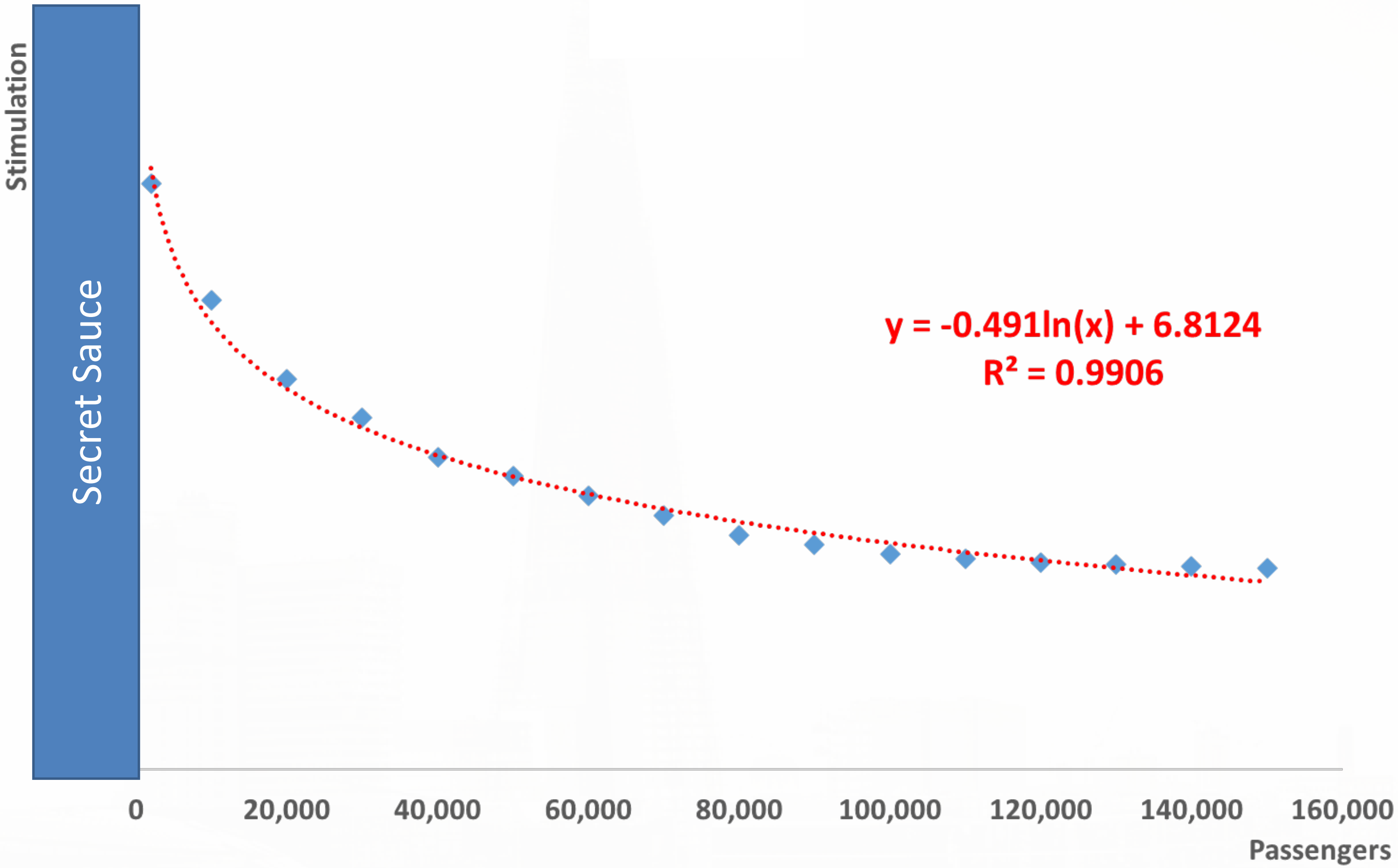
Manchester - Norwich	
Straight line distance	158 miles
Driving distance	204 miles
Travel time (cars)	244 minutes
Travel time (public transport)	267 minutes
Flight time* (advanced air mobility)	109 minutes
Flight time vs drive time (cars) ratio	0.45
Flight time vs public transport ratio	0.41
Straight line vs drive time distance ratio	0.77

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

Routes Identification

Route	Distance (m) (driving)	Distance (m) (straight line)	Travel time (min) (cars)	Travel time (min) (public transport)	Flight time (min) (advanced air mobility)	Population combined (route)	Drive distance vs straight line ratio	Flight time vs cars ratio	**Flight time vs public transport ratio**
Xxx - Aberdeen	279	180	345	376	120	250,302	0.65	0.35	0.32
Xxx - Wider Southampton	164	142	189	276	101	1,623,207	0.87	0.53	0.37
Birmingham - xxx	243	198	258	349	128.5	2,917,645	0.81	0.50	0.37
Manchester/Liverpool - xxx	185/192	132/154	185/200	245/258	96	2705066/864188	0.71	0.52	0.39
Manchester/Liverpool- xxx	204/252	158/186	244/307	267/277	109	2918166/1077288	0.77	0.45	0.41
xxx- Brighton	158/127	114/104	180/182	201/180	87	1,081,445	0.72	0.48	0.43
Leeds Bradford - xxx	176/184	130/135	162/171	187/197	95	2,035,000	0.74	0.59	0.51
Leeds/Bradford- xxx	207/214	168/166	172/182	214/252	114	2625934/724067	0.81	0.66	0.53
Birmingham - Edinburgh	287	246	320	240	152.5	3,385,353	0.85	0.48	0.64
London-Glasgow	405	345	421	297	202.5	11,964,290	0.85	0.48	0.68
Birmingham - Glasgow	291	252	302	228	156	3,882,593	0.87	0.52	0.68
Xxx - London	127	109	154	114	84	11,747,638	0.85	0.55	0.74
London-Edinburgh	379	332	430	260	196	11,467,050	0.88	0.46	0.75
Xxxx - Leeds	155	100	177	96	80	1,902,016	0.65	0.45	0.83
Leeds/Bradford – London	194/201	169/172	190/201	132/160	114.5	12880934/10979067	0.87	0.60	0.87

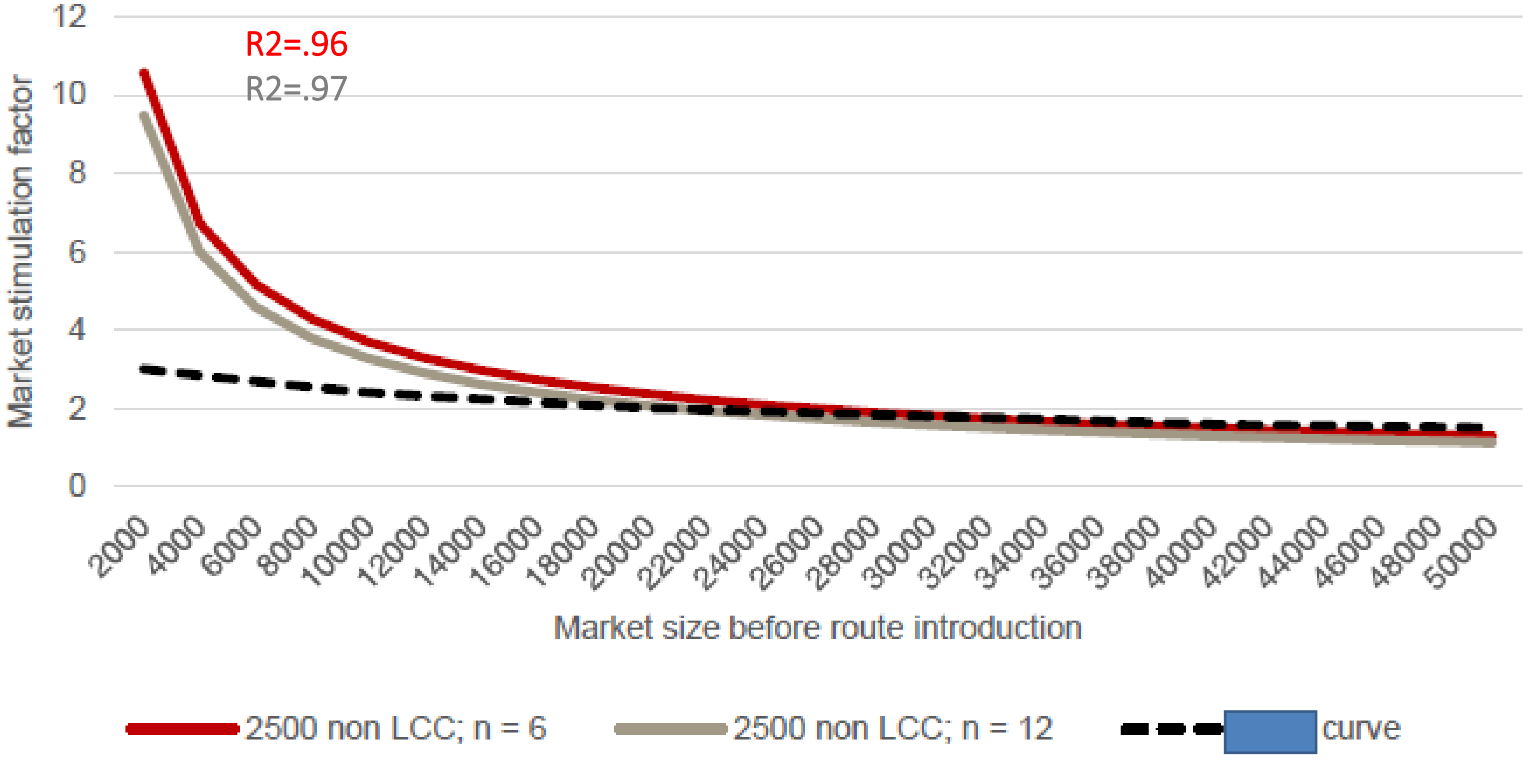
Routes Identification – Stimulation Curve



- 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.

Routes Identification – Independent Analysis of Market Stimulation

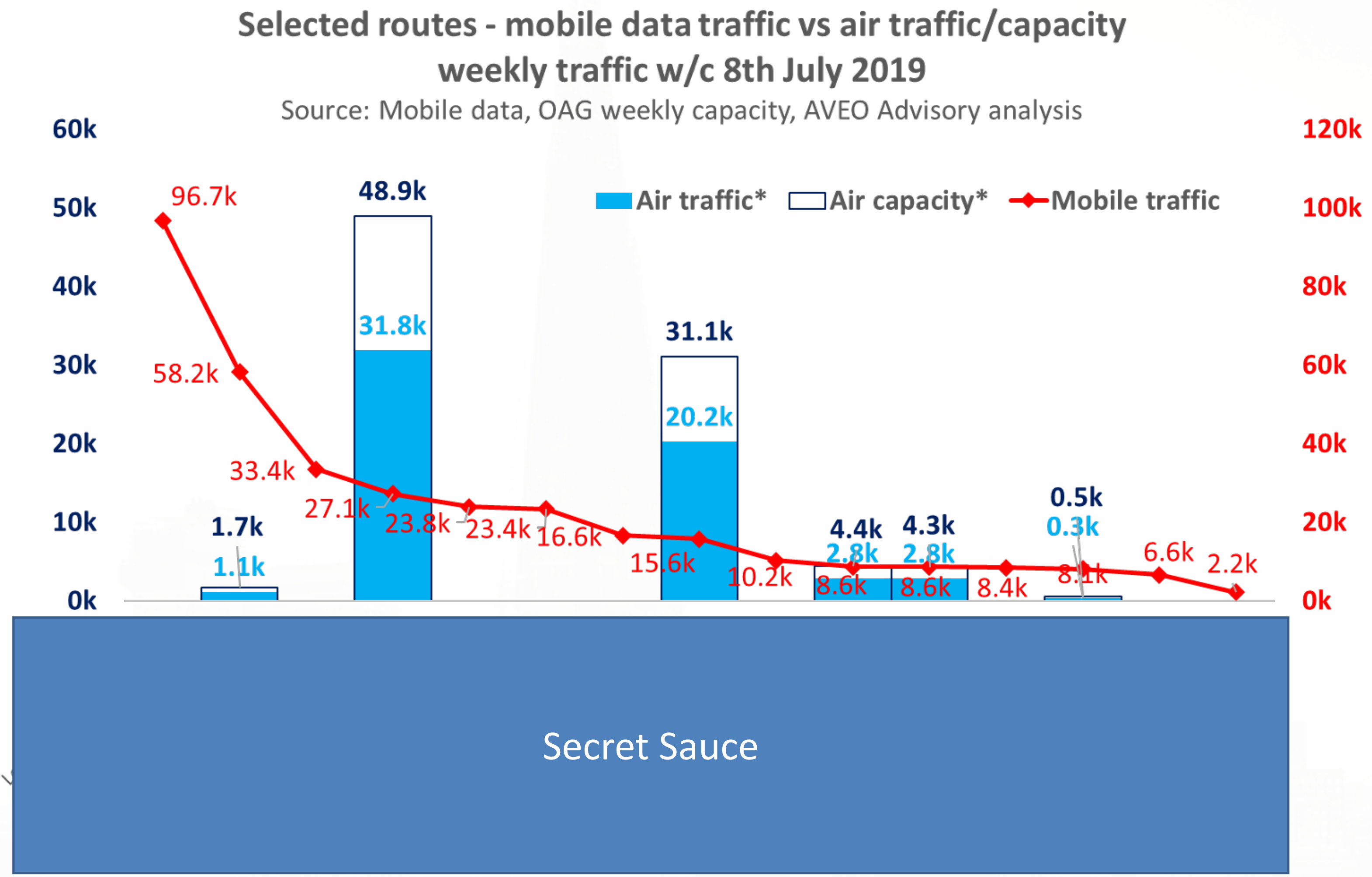


- Other independent market stimulation analysis indicate higher stimulation impacts can be found for regional routes with small initial market sizes compared to XXXX stimulation curve.

- 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.

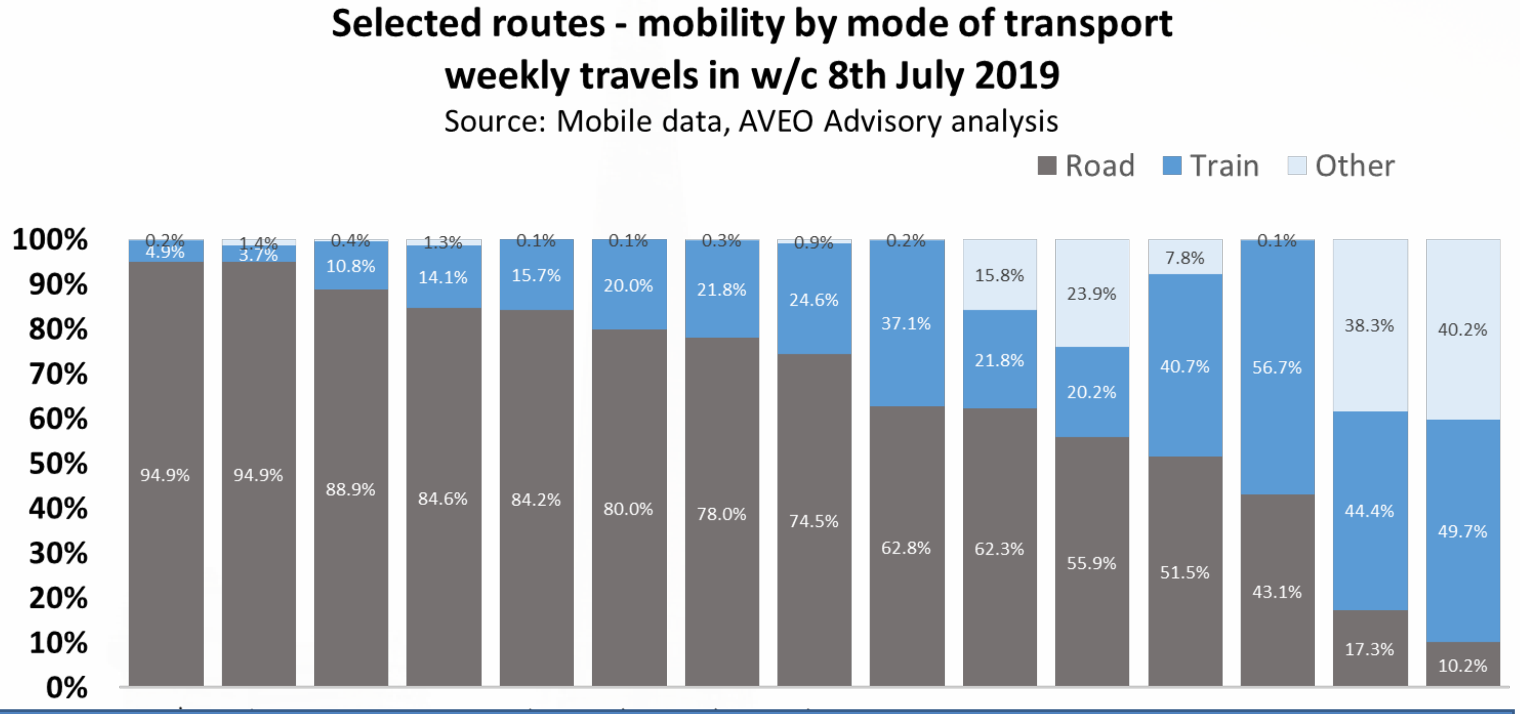
- For this exercise, the XXXX stimulation curve has been used to reflect a conservative approach.

Routes Identification – Air Traffic vs Mobile Traffic Data



- On the 15 selected routes, 6 of them are 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 air included in the air traffic dataset).

Routes Identification – Mobility by Mode of Transport



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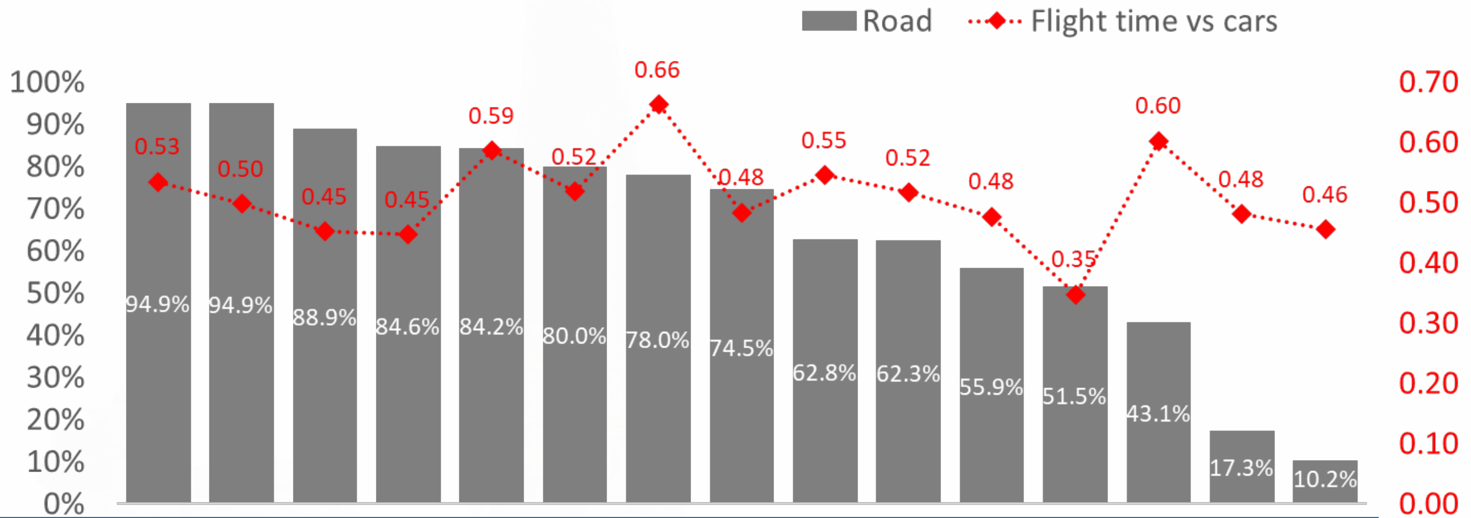
- The most popular mode of transport between the selected cities is private cars and public transport (trains).
- Air travel prevails only on two routes, GLA-LHR and EDI-LHR, mostly due to long distances and very long travel time by surface transport.
- Interestingly, for routes such as Birmingham – 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.

Routes Identification – Flight Time vs Surface Transport Ratios

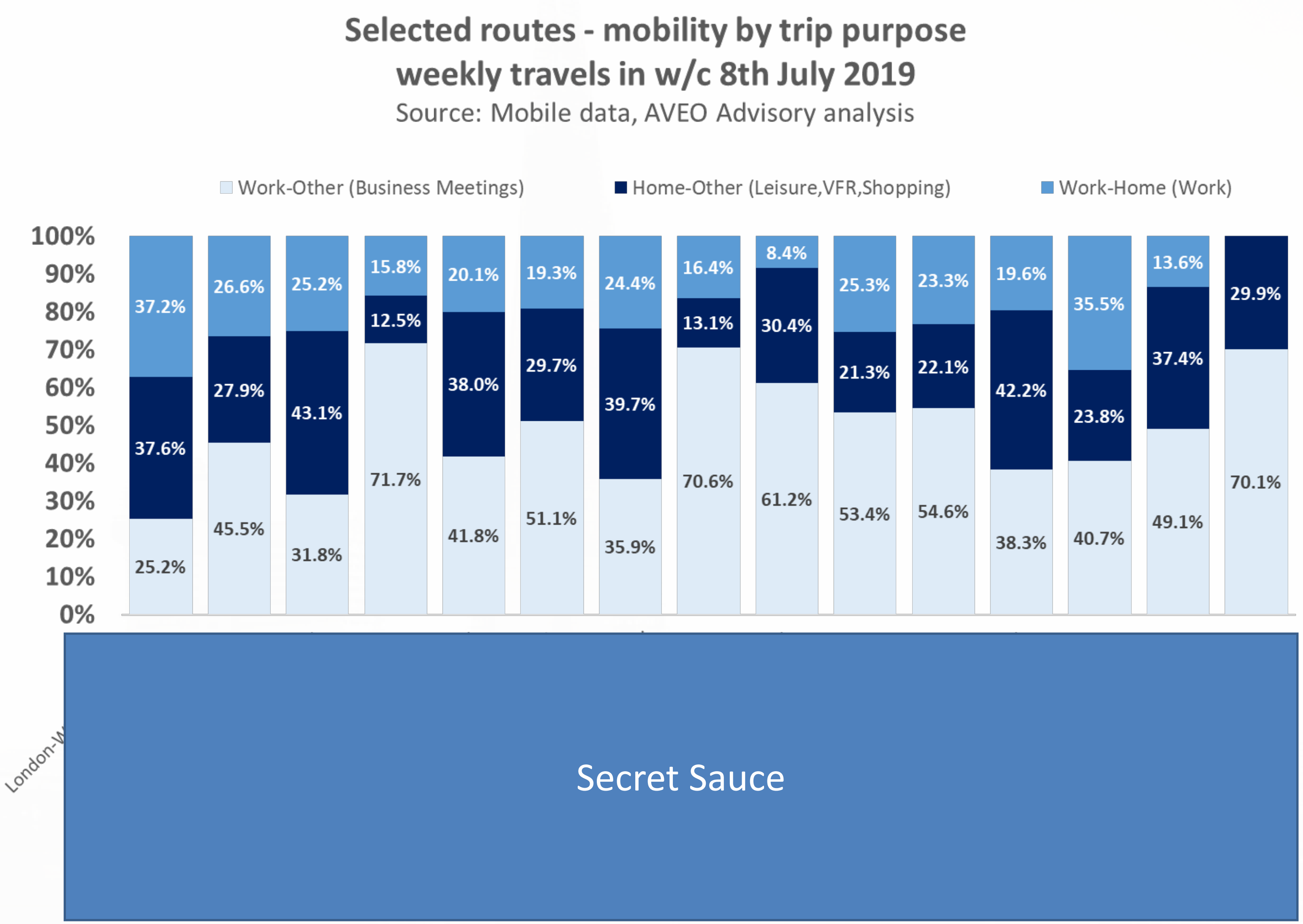
Flight time vs drive time cars ratio and % of traffic by road weekly travels in w/c 8th July 2019
Source: Mobile data, AVEO Advisory analysis



Secret Sauce

- 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.

Routes Identification – Mobility by Trip Purpose



- 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.**

Route exceeding 240 km (150 m) – not suitable range-wise for a 4 seats eVTOL

Routes Identification - Possible AAM Operations

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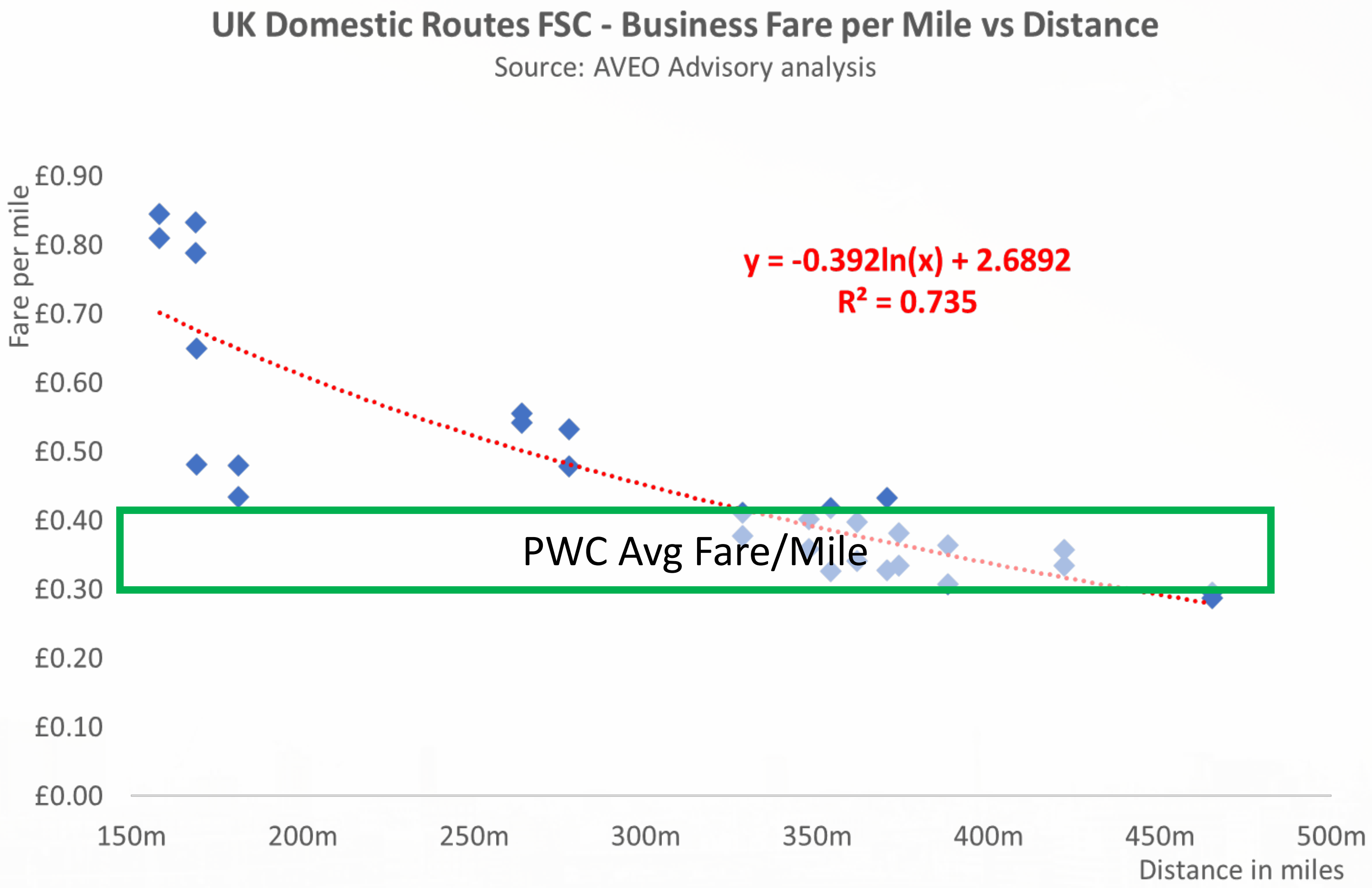
Manchester/Liverpool- xxx	481			19,440	0.05	996	90%		21	14	11	7
Leeds/Bradford-London	1,703			83,577	0.05	4,264	90%		91	61	46	29
xxx -Leeds/Bradford	-			23,361	0.05	1,168	90%		25	17	13	8
Glasgow-London	31,070			32,540	0.05	3,181	90%		68	45	34	22
Edinburgh-London	48,940			49,124	0.05	4,903	90%		105	70	53	33
Brighton- xxx	-			19,971	0.05	999	90%	32	21	14	11	7
Birmingham- xxx	-			43,999	0.05	2,200	90%		47	31	24	15
Birmingham-Edinburgh	4,360			20,385	0.05	1,237	90%		27	18	13	8
Birmingham-Glasgow	4,259			20,342	0.05	1,230	90%		26	18	13	8
Xxx -Manchester/Liverpool	-			44,656	0.05	2,233	90%	72	48	32	24	15
London- xxxx	-			114,799	0.05	5,740	90%	184	123	82	61	39
xxx -Leeds/Bradford	-			57,063	0.05	2,853	90%	92	61	41	31	19
Xxx - xxx	-			34,078	0.05	1,704	90%	55	37	24	18	12
Leeds/Bradford- xxx	-			16,497	0.05	825	90%	27	18	12	9	6
Aberdeen- xxx	-			6,632	0.05	332	90%		7	5	4	2

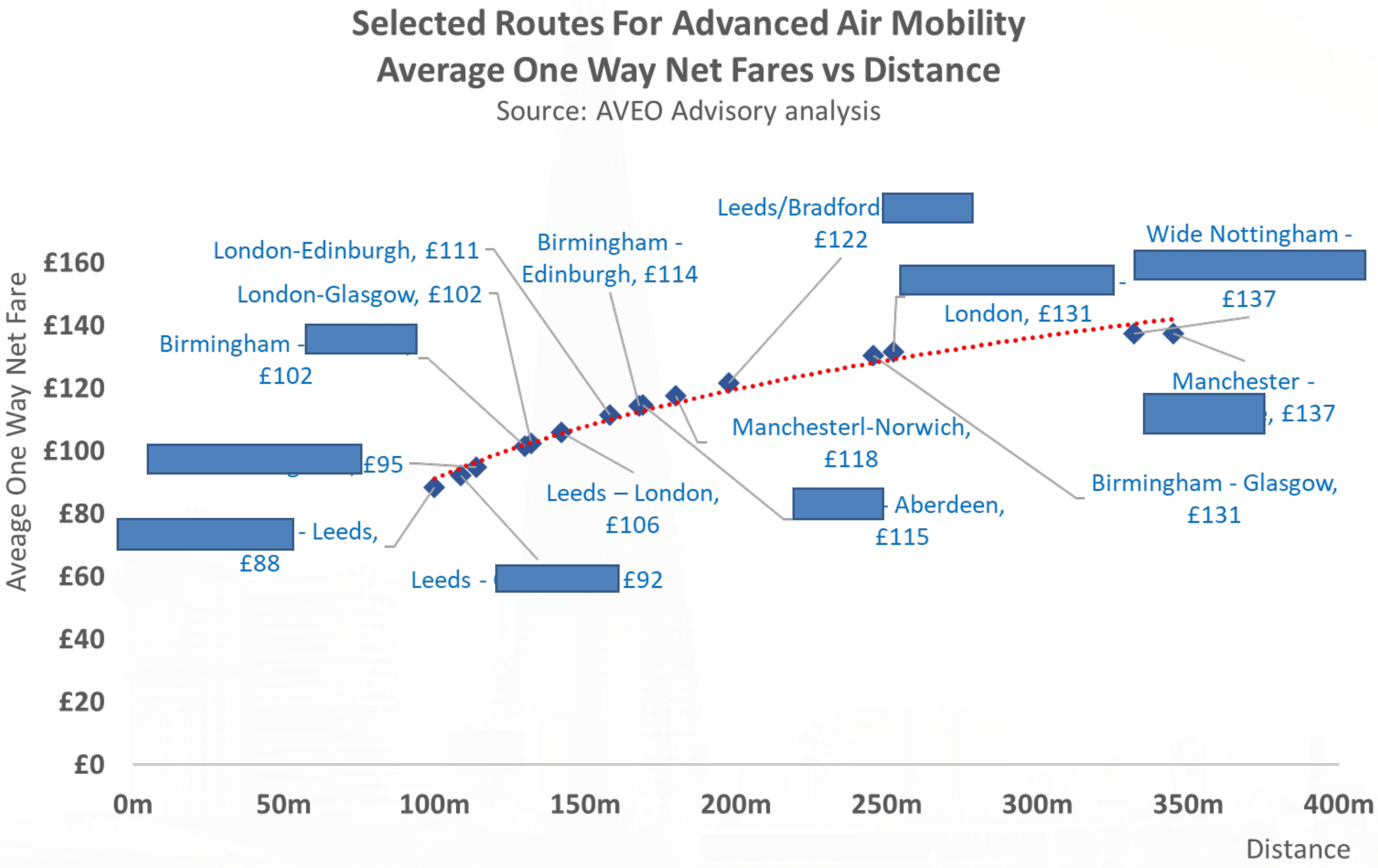
Routes exceeding 240 km (150 m) – not suitable range-wise for a 4 seats eVTOL

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 Strucure



- 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.

The Big Numbers

7 Days

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 reclaim + 1m for SE connectivity

1 working yr

Time Savings
(over Road & Rail)
625yr

Economic Reclaim
(over Road & Rail)
£198m

Carbon Savings
(over Road & Rail)
80k tons

Levelling Up
(over Road & Rail)
£50.6m economic reclaim + £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

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