UK Research and Innovation

Date 2022

UK Advanced Air Mobility (AAM) Market Assessment

An analysis of 20 potential routes in the UK for AAM aircraft operations

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1. The Big Numbers

Swanson Aviation Consultancy Limited, operating under the brand ElectricAviation Maven or EAMaven, was engaged to undertake an assessment of potential routes across the UK with the aim of identifying the potential for electric aviation aircraft.

The purpose of the study was to illustrate the potential for electric aviation in the UK using a mix of electric vertical take-off and landing (eVTOL) and electric conventional take-off and landing (eCTOL) aircraft.

EAMaven has developed a methodology to predict the potential demand between destination pairs, using a modified traditional airline prediction model. This is based on a blend of traditional data sources and new mobility data.

Route Assessment:

14 eCTOL routes and 6 eVTOL routes. The routes chosen were a mix of potential services that would address the Government's 'levelling up' and 'northern powerhouse' agendas, as well as the Union Connectivity Review.

Total Aircraft required:

224 in total, made up of 160 four-passenger eVTOL and 64 19-passenger eSTOL aircraft.

Annual revenue generation:

£704 million per year, equating to just over £3.1 million in revenue being generated per aircraft.

Average aircraft utilisation:

1,854 hours per year. eVTOL are being flown on average 1,965 hour per year and eCTOL on average are being flown 1,581 hours per year.

Economic stimulation:

Through increased productivity, £2.6 million per week was put back into the economy, or £124 million annually, using Department for Transport (DfT) WebTAG benchmarks.

Time Savings:

11 person years per week, or 528 person years on an annual basis.

Carbon Emissions Savings:

Based on attracting travelers away from car journeys, we calculated that, on an annual basis, we would reduce carbon emissions from cars by 9,000 tonnes.

The Big Numbers at a glance

14

ECTOL ROUTES

6

EVTOL ROUTES

160

4 PASSENGER EVTOL AIRCRAFT

64

19 PASSENGER ESTOL AIRCRAFT

224

TOTAL AIRCRAFT REQUIRED

ECONOMIC STIMULATION THROUGH INCREASED PRODUCTIVITY =

£2.6m

PER WEEK

£124m

PER YEAR

£704m

ANNUAL REVENUE GENERATED PER YEAR =

£3.1m+

IN REVENUE GENERATED PER AIRCRAFT

9,000

TONNES OF CARBON EMISSIONS REDUCED FROM CAR JOURNEYS

1,854

AVERAGE UTILISATION HOURS PER YEAR PER AIRCRAFT

TIME SAVINGS =

11

PERSON YEARS SAVED PER WEEK

OR

528

PERSON YEARS ANNUALLY

1.1. FORWARD

The centralised model of the current hydrocarbon aviation network has, for so long, been seen as the only real solution for air travel in the UK – and for much of the world. Described as a 'hub-and-spoke' concept, consisting of restricted direct routes that meet the criteria of demand and commercial viability, the system often bypasses the needs of people and businesses at a regional level, leaving them disconnected without the option of air travel.

Conversely, low cost airlines in many instances have developed a point to point system but rather than use hub airports, use smaller airports outside the destination city. These airports usually offer lower landing charges and needed capacity. The aircraft manufacturing industry has responded with the development of newer aircraft that are meant to address the long-haul low-cost market known as 'hub busters'.

A future system that disrupts this status quo is evolving. Low on environmental impact, but high in economic contribution, a new sub-regional air mobility sector can offer flexible and commercially-viable solutions to these issues – with the environmental benefits that come with electric and hybrid power too.

The key here is in creating connections. Working alongside, and connecting with, existing transport networks and the current aviation sector itself, this future concept of 'distributed aviation' aims to bring together a more closely woven, complementary and effective transport system in the UK.

Whether connecting rural or remote areas previously unsupported by air transport, or providing an urban solution that tackles congestion, noise pollution and flexible travel, distributed aviation and the future flight model more broadly, brings a compelling case. This latest research will now dig deeper into its viability and potential for success.

Additional information on the concept of a Distributed Aviation system can be found in the ADS paper referenced below which was authored by Darrell Swanson and Jarek Zych with the support of others.

1.2. ABOUT THE AUTHORS

ElectricAviation Maven or EAMaven (www.EAMaven.com) are a leading expert in advanced air mobility demand modelling, system planning and infrastructure design. Through our unique approach to demand modelling and our Distributed Aviation analysis EAMaven can help clients identify opportunities within the Advanced Air Mobility Sector. Our client's portfolio comprises OEMs, airports, airlines, infrastructure investors, governments and more. Our aim is to help our clients assess the potential that AAM revolution will bring to their business.

Darrell Swanson is a specialist on electric aviation and how it will lead to a future of distributed aviation. His knowledge encompasses electric aircraft infrastructure requirements and demand modelling for emerging electric Low Cost Carriers (eLCCs).

He is an advisor to NASA's Transformative Vertical Flight groups 2 & 3, the Advanced Air Mobility panel at ADS, the Community Air Mobility Initiative and a board member of the British Aviation Group the largest trade body in the UK representing over 200-member companies.

Darrell has 20+ years' experience as an aviation consultant on airport masterplanning projects thru to airport acquisition advisory services.

- Electric aviation thought leader with reference to the evolution of Distributed Aviation as enabled by electric propulsion systems.
- Development of country wide demand modelling for electric aircraft operators
- NASA TVF Working Group Leader/Advisor
- Board member of the British Aviation Group
- Advisor to NASA, CAMI, ADS AAM, VFS, Flight Crowd and Civata Global on Electric Aviation
- 25 years' experience in airport masterplanning, design, acquisition due diligence.

Qualifications

- Diploma – Airport Management and Operations – Georgian College
- MSc – Airport Planning and Design – Loughborough University
- MBA – Strategy – Bayes Business School - London

Jarek Zych has spent the last 16 years working for and providing services to leading aviation companies including airlines, airports, leasing companies, aviation consulting firms and suppliers.

He specializes in demand modelling for advanced air mobility, air service development and traffic forecasting for airports, and network, fleet and schedule planning / strategy for airlines. He has in-depth knowledge of aviation market data, including QSI modelling, short and long term traffic and revenue forecasting, MIDT/BSP/ARC/US DoT data, schedules and fleet.

Jarek Zych is also the Founder of AVEO Advisory where he acts as an Independent Advisor. Prior to EAMaven, he held a number of mid-senior positions at leading aviation firms:

Cirium – Sales Engineer EMEA

Advising world's leading airlines and airports on their business by providing traffic, schedule and real-time aircraft operations data solutions.

Avia Solutions – Management Consultant

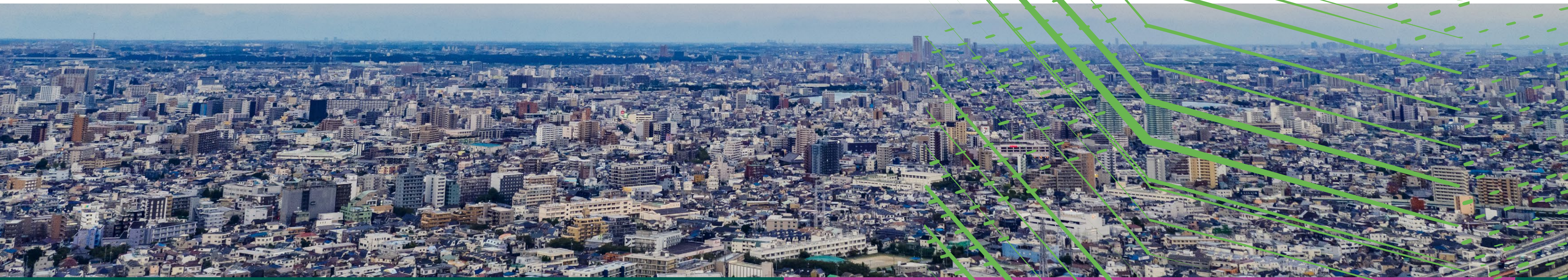
6+ years managing a variety of projects on behalf of airports, airlines, governments and aviation investors worldwide. Involved in market strategy analysis, air service development, traffic forecasting and network planning for numerous airports and airlines in the US, Middle East, South East Asia, Africa and Europe.

Warsaw Chopin Airport – Network Development

6+ years responsible for all air service and network development activities including airline liaison.

Qualifications

- BSc in Civil Engineering
- MSc in International Management from University of Warsaw
- Postgraduate degree in Air Transport Sector Management and Finance from Warsaw School of Economics Warsaw University of Technology
- Air Transport Marketing courses at University of Westminster
- Management and Leadership courses in New York and Amsterdam and Airport Council International courses in Bologna



1.3. ELECTRIC AVIATION FUNDAMENTALS

Electric aviation presents an unprecedented opportunity in the aviation sector not seen since the very early days of aviation. This innovation has come about through the incremental development of electric propulsion systems, which has its roots in electric car manufacturing.

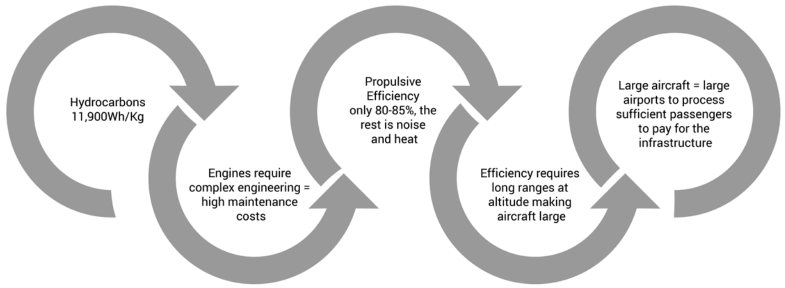
1.1.1. The Economics of Hydrocarbon Aviation v Electric Aviation

In the new world of electric aviation, the economics are very different. As engine technology evolved, the efficiency and complexity of hydrocarbon-powered aircraft increased, requiring aircraft to become larger, carrying more passengers over longer distances. This, in turn, meant larger airports to be able to pay for the whole system. Consequently, large hub-and-spoke airport systems were a natural economic outcome.

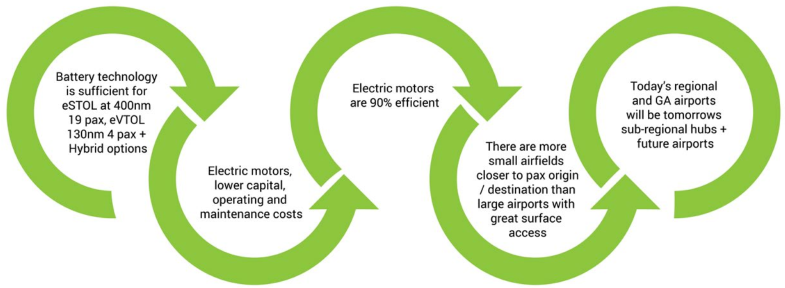
Conversely, electric aircraft, due to their lower capital, operating, and maintenance cost, will be able to operate out of smaller airfields at lower costs - which may also be closer to the passenger's true origins and destinations.

An analysis of Regional Jet and Turbo Prop aircraft operations in Europe in 2017 shows a trend whereby regional aircraft manufacturers are developing aircraft with increased range and seat capacity, whereas airlines' peak average sector length was only 370km accounting for 47% of the frequencies offered. In this case, aircraft with a range of up to 4,500km are being operated on sectors of up to 1,000km, or only 11% of their range capability. Electric aircraft can operate in this 'sweet spot', which are those routes of less than 500km in distance, thus addressing 5% of aviation carbon emissions.

Economics of Hydrocarbon v Electric Aviation

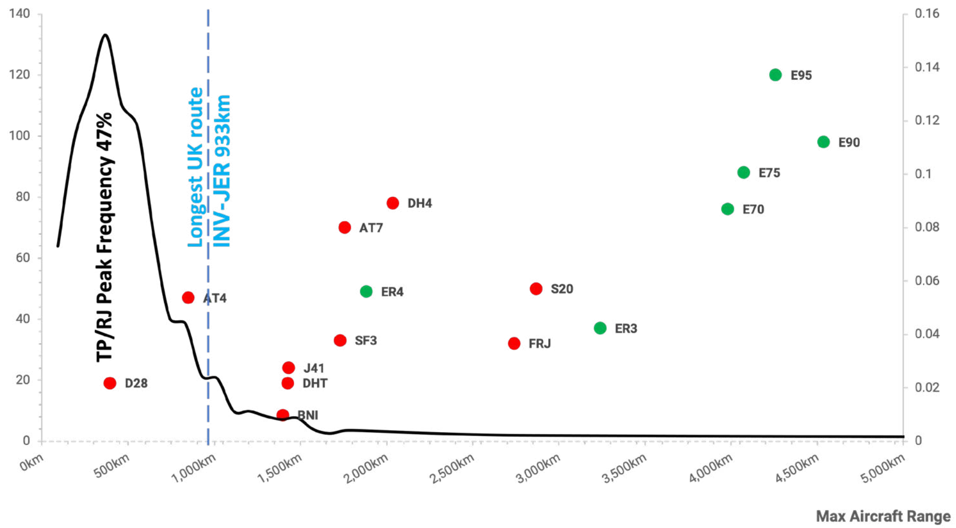


Economics of Hydrocarbon v Electric Aviation



Regional Jets/Turbo Props Frequence Distribution vs Distance/Max Range Europe

Source: EAMaven analysis, OAG Schedules



1.1.2. The Rise of Distributed Aviation

The opportunity presented by electric aircraft is that a distributed aviation system can be developed that allows the industry to make the best use of existing aviation infrastructure, while still increasing regional connectivity - leading to increased economic benefit. The evolution of a distributed aviation system is set out below:

- Early electric aircraft operators will operate out of smaller airports and vertiports, having first-mover benefits in these markets. As the density of future electric aircraft operators increases, more routes will be opened as they seek new markets.
- Sub-regional airline solutions, in the form of electric low-cost carriers (eLCCs), will evolve and operate on thinner routes with lower demand. This is enabled by the lower capital, operating and maintenance cost of electric aircraft.
- A quantity of sub-regional traffic will distribute away from the current hub-and-spoke system of airports to regional/secondary and smaller airports.
- eLCCs will operate out of regional/secondary and smaller airports due to their lower charges, available capacity, and closer proximity to markets which are viable, even though they are uneconomic for hydrocarbon-powered airlines.
- Fixed-wing electric aircraft will take passengers over longer distances where they will transfer onto either local transportation services or an eVTOL for access into large urban environments. As technology permits, direct city centre to city centre eVTOL operations will be established.
- A distributed electric aviation system offers lower-cost, sub-regional flights closer to passengers' origins and destinations, while helping reduce the carbon impact of travel.
- Larger international airports may lose some domestic traffic but gain in terms of a reduction in the number of smaller, less-profitable routes, which can be replaced with long-haul international flights, while still maintaining regional connectivity. This has the potential to make the best use of our existing hub airports and their precious runway slots, whilst still accommodating growth.
- In supporting electric sub-regional flights, this will allow sustainable aviation fuels to be utilised on long-haul aviation routes - further reducing the impact of aviation on the environment.
- As electric aviation technologies develop, they will enable larger aircraft, which will be incorporated into our well-established aviation system, to help the aviation industry meet its carbon commitments.

1.4. THE PURPOSE OF THE STUDY

The purpose of the study is to highlight the potential for electric aircraft operation in the UK domestic market. The analysis will demonstrate the frequencies accessible on the selected origin/destination (OD) pairs as an indication of how electric aircraft can contribute to regional connectivity, whilst reducing the carbon impact of travel.

The study will also provide an indication of carbon emissions savings over the identified routes from passengers switching from road to Advanced Air Mobility (AAM) modes of transport. This is based on benchmarked modes of transport using DfT sources and the aggregated sources of energy (the 'energy mix') available in the UK.

The study also identifies the potential revenue generated by flights, as well as the economic stimulation that is attributed to increase productivity of travellers spending less time in a car or on a train.

Additionally, the study will identify the number of aircraft needed (both fixed-wing and eVTOL) for the identified routes, as well as provide insights into energy requirements.

1.5. METHODOLOGY

EAMaven worked together with UK Research & Innovation (UKRI) in advance of the study in order to understand and agree the most appropriate methodology, and to ensure it was effective for the purpose of the research.

The basis of the methodology uses traditional aviation forecasting techniques employed by airports and airlines, blended with ground transportation forecasting techniques and novel sources of data. Traditional data sources include schedule and fare data available from various providers. The novel sources of data include DfT studies, online datasets and data provided by mobile phone operators. The blending of these different sources of data allows unprecedented insights into mode of transport, purpose of travel, time of travel and ultimate origin and destination, within the confines of General Data Protection Regulations (GDPR).

In the first instance, traditional data sets, including schedules and fare data, are used to understand the existing sub-regional market to identify existing travel options and pricing levels. This data provides the basis for assessing which passengers could be attracted away from traditional hydrocarbon aviation routes to new AAM services.

In the second instance, using a blend of traditional aviation models and ground transportation forecasting techniques, an assessment of the likelihood of travellers switching modes of transport is undertaken. This method is based in mode choice models, but enhanced with other data to identify critical factors affecting people's choice of transport.

Based on this blended approach, potential demand per route is calculated for each mode and purpose of transport for the time of day.

This information is then used in a scheduling tool that first looks to understand the required number of aircraft to service the route. Manual fine tuning is then required to optimise a schedule, ensuring the maximisation of aircraft utilisation, whilst still satisfying a reasonable level of demand and minimising empty flights. The scheduling tool is then used to generate information, including: aircraft utilisation, economic benefit, carbon emissions savings, as well as infrastructure requirements.

1.6. BOUNDARY CONDITIONS OF THE STUDY

The Origin/Destination Pairs

The study is limited to a select set of OD pairs which was chosen to reflect a range of potential routes for both fixed-wing electric aircraft and eVTOL vehicles. Specifically, some routes were chosen to address the UK Government's 'levelling up' and 'Northern powerhouse' agenda. Additionally, some routes were included to address the Union Connectivity Review, to demonstrate how AAM could contribute to increasing connectivity within and among the four UK nations, as well as looking at routes where there are existing air services to act as a comparison.

UKRI and EAMaven worked together to agree appropriate potential locations for AAM activity, recognising that, in each case, the appropriate planning application processes would need to be executed to determine their ultimate compatibility. As various commercial and location sensitivities exist for activities of this nature, half of the exact location of the OD pairs has been obscured throughout this study.

Potential Volume of Traffic

The demand that was calculated and used to derive indicative schedules assumed that infrastructure and aircraft are available to be deployed on the identified route. There was no consideration given to how an operator of such aircraft may actually 'ramp up' operations over a period of time.

Rational Operator

With reference to the scheduling exercise, the tool generated the number of flights needed to satisfy the demand, with consideration given to overall aircraft utilisation. As a result of this, the average aircraft utilisation, in terms of number of flying hours per year, may seem low in some cases. However, what this shows is the minimum number of potential operating hours. In reality, a rational aircraft operator would restrict supply to the point where it affects demand and rationalise the number of aircraft put on a specific route, which would increase aircraft utilisation.

Network Effect

With reference to aircraft utilisation, the scheduling tool only looked at each route in isolation – thus, there is no network effect that would increase aircraft utilisation. A rational operator would seek to optimise the scheduling of aircraft across multiple routes to ensure that aircraft utilisation is at its peak within their operating criteria.

Peak Hour Profiles

The travel patterns observed have significant peaks, with an expected early morning and late afternoon peak, combined with a midday off-peak period. In the first iterations of the demand study, the peak aircraft requirement generated was significant, resulting in a number of aircraft flying empty or with very low load factors - or effectively 'dead heading' as they returned to their origin effectively empty. With reference to a rational operator, we applied a smoothing of the peak hour distribution of the traffic. The rationalisation for this is that, in general in the aviation industry, travellers will adjust their schedules to take advantage of the service offered.

Additionally, in most cases the time savings offered by flight is significant, offering travellers more effective time in their day. Therefore, they would be more willing to switch to a later service. Additionally, it is assumed that a yield optimisation approach to fare management would be enacted, thus shifting demand from peak to shoulder periods. The net effect of this was to reduce the number of aircraft required and increase aircraft utilisation.

2. Summary

The following table sets out the OD pairs, with distance, driving/public transport time, aircraft type and travel time for AAM modes of transport based on assumptions set out below.

Route	Travel time (min) (cars)**	Travel time (min) (public transport)**	AAM Aircraft type	Flight time (min) (advanced air mobility)***	Population combined (catchment areas)	Flight time vs cars ratio	Flight time vs public transport ratio
Redcar-XXX	345	376	eSTOL	76	250,302	0.22	0.20
Wider Southampton-XXX	189	276	eSTOL	65	1,623,207	0.34	0.24
Cornwall-XXX	258	349	eSTOL	81	2,917,645	0.32	0.23
Manchester/Liverpool-XXX	185	245	eSTOL	62	2,705,066	0.34	0.25
Norwich-XXX	244	267	eSTOL	70	2,918,166	0.29	0.26
Bristol-XXX	180	180	eSTOL	57	1,081,445	0.32	0.32
Leeds/Bradford-XXX	162	187	eSTOL	62	2,035,000	0.38	0.33
Leeds/Bradford-XXX	172	214	eSTOL	73	2,625,934	0.42	0.34
Edinburgh-XXX	320	240	eSTOL	95	3,385,353	0.30	0.40
London-XXX	421	297	eSTOL	124	11,964,290	0.29	0.42
Glasgow-XXX	302	228	eSTOL	97	3,882,593	0.32	0.43
Wider Nottingham-XXX	154	114	eSTOL	56	11,747,638	0.36	0.49
London-XXX	430	260	eSTOL	120	11,467,050	0.28	0.46
Peterborough-XXX	177	96	eVTOL	63	1,902,016	0.35	0.65
London-XXX	190	132	eSTOL	73	12,880,934	0.38	0.55
Belfast-XXX	100	167	eVTOL	48	493,669	0.48	0.29
Peterborough-XXX	135	50	eVTOL	53	9,205,114	0.39	1.05
Pembrokeshire-XXX	125	450	eVTOL	53	495,953	0.43	0.12
Inverness-XXX	165	133	eVTOL	56	275,930	0.34	0.42
Sheffield-XXX	120	77	eVTOL	49	1,729,739	0.41	0.64

* Mobile phone data, both ways including catchment areas
** AM Drive times (arrive by 9:00am) – an average taken from the best and the worst case scenario
*** for eVTOL – Flight times based on an exemplary eVTOL (4 seater) speed profile (155mph). Process times based on other analysis (17 min to board, de–board, taxi and take-off) + 9 minutes for ascend/accelerate/decelerate/descent/hover
*** for eSTOL – Flight times based on an exemplary eSTOL (19 seater) speed profile (255 mph). Process times based on other analysis (20 min to board, de-board, taxi and take-off) + 4 minutes for ascend/descent)

The initial analysis is to look at the ratio between flight time and travel time by other modes of transport. In general, the lower the ratio the higher the utility of AAM modes of transport.

The straight-line distances between the centre of the study locations range from 99km for Belfast, to 552km for London to Glasgow which would now be accessible by the Heart Aerospace ES-30. Additionally, the combined population of the catchment areas is provided to give context to the potential market that is being served.

An analysis of scheduled data between airport pairs and mobility data confirms that there is significant under provision of air services, which is not unexpected. This is likely due to the higher cost of domestic air travel, which is a fundamental of hydrocarbon aviation services.

When assessing the routes, attention is paid to the mode of transport between the OD pairs, as there is a preference to draw travellers from road as opposed to rail - except where poor services are offered.

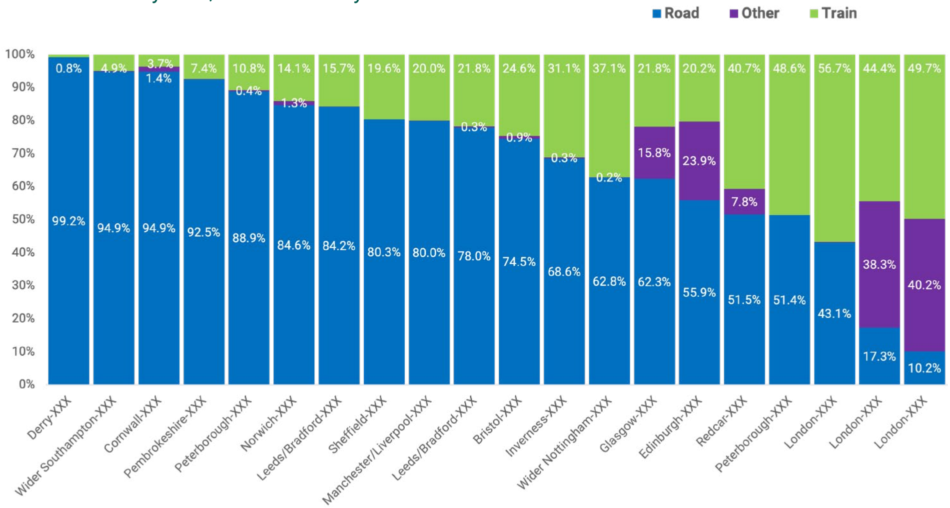
Air travel prevails only on two routes, Glasgow to Heathrow and Edinburgh to Heathrow, mostly due to long distances and travel time by surface transport.

It is noted that for the selected route from Belfast (99.2%), as well as the route out of Birmingham and into Southampton (both 95%), the major mode of transport is cars. Other modes of surface transport are marginal (mainly due to availability). This creates an opportunity for advanced air mobility to gain a significant market share.

For the top five routes with the largest share of cars as the main mode of transport, the flight time ratio vs drive time ratio is relatively low, and varies from .32 to .48 (see below). Thus, these OD pairs are very hard and time consuming to travel between, therefore more car users would theoretically switch to advance air mobility services, with some significant time and economic gains.

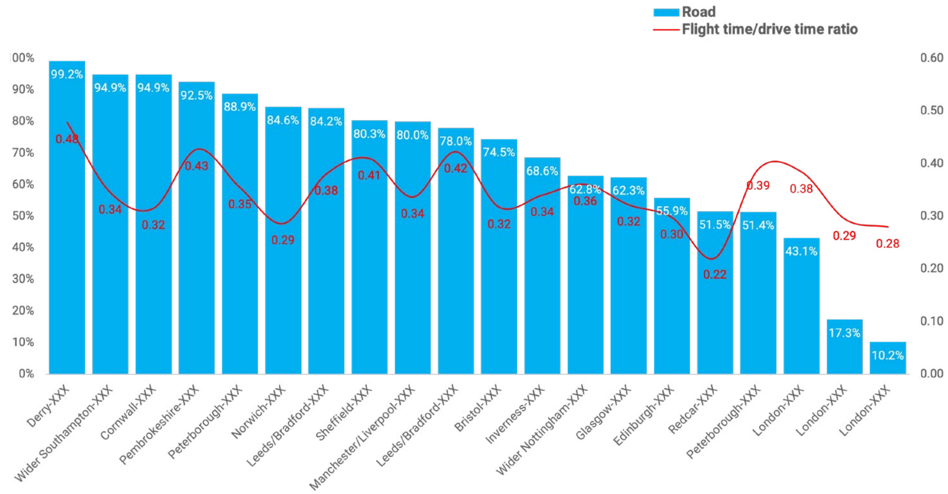
20 routes: mobility by mode of transport weekly travels

Source: Mobility data, EAMaven analysis



Flight time vs drive time cars ratio and % of traffic by road weekly travels

Source: Mobility data, EAMaven analysis



For those 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. This is due to the distance between the two cities and the fact that the rail services may have several stops, which may increase the need to change trains increasing the overall journey time.

Only one route, from London to Peterborough, offers a similar travel time compared to AAM and therefore may not necessarily be a good example of a potential AAM route.

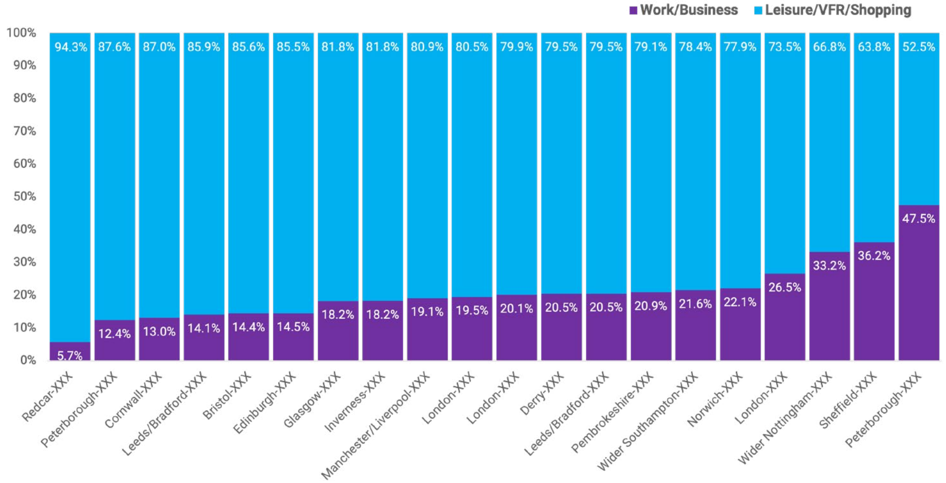
The data also provides additional insights into the purpose of the journey and, for this analysis, it has been divided into work/business-related travel, leisure/visiting friends and relatives, and retail, as broad categories.

The analysis shows that the impacts on work and business travel vary from 5.7% on a Redcar route to 47.5% on the Peterborough to London route.

As a main indicator of mobility, an assessment of mobility per 100,000 travellers was undertaken. Routes with the total combined population of up to 1 million offer the highest mobility per 100,000. It was noted that highly urbanised and populated areas have a low mobility per 100,000 index, which may suggest that Regional Air Mobility (RAM) routes may have more utility to travellers.

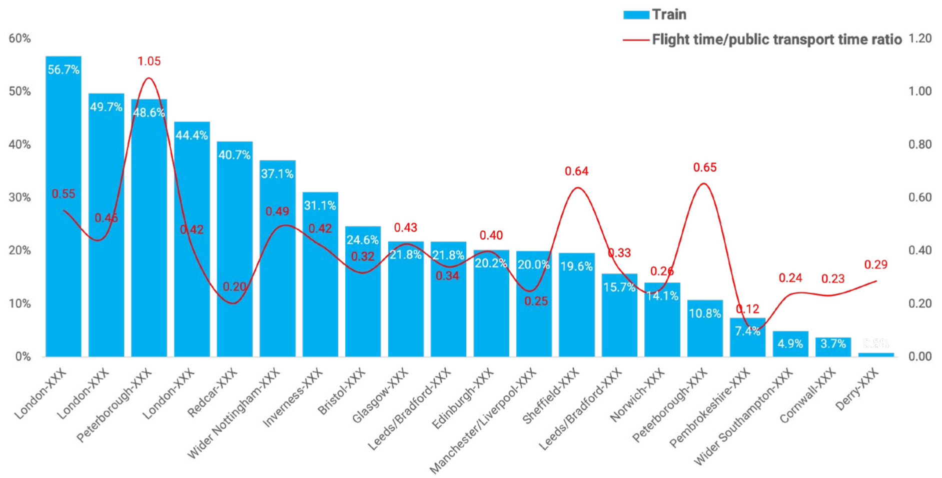
20 routes – mobility by trip purpose weekly travels

Source: Mobility data, EAMaven analysis



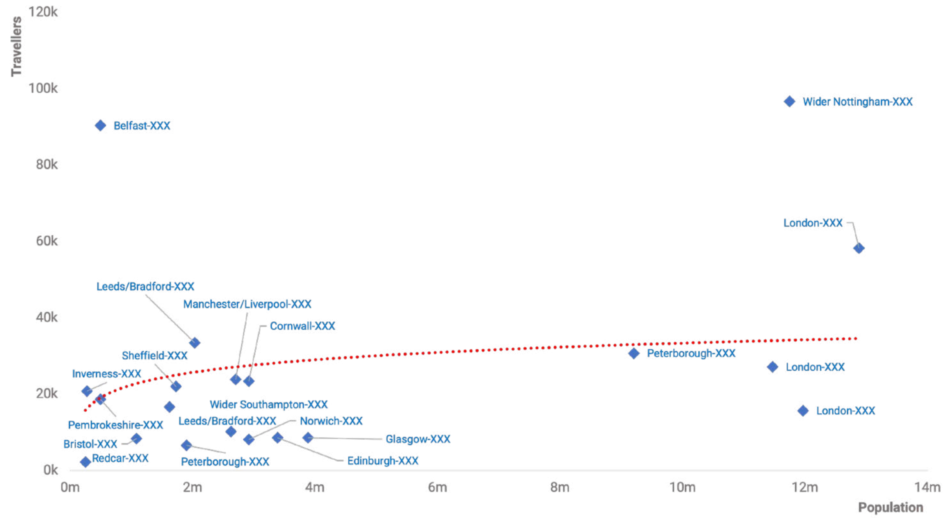
Flight vs public transport time ratio and % of traffic by train weekly travels

Source: Mobility data, EAMaven analysis



20 routes – population vs mobility weekly data traffic

Source: Mobility data, EAMaven analysis



3. An Estimation of Demand

The following table sets out the demand assessment between the 20 origin/destinations which was taken through an iterative process to smooth peak demand and account for the effect of scheduling on demand.

			Summary Annual				
Route	Total initial weekly demand	AAM aircraft type	Demand	Capacity	LF%	Flight time/ drive time ratio	Flight time/ public transport time ratio
Wider Nottingham-XXX		eSTOL	200,037	187,872	106.5%	0.43	0.58
London-XXX		eSTOL	159,776	175,104	91.2%	0.32	0.40
Leeds/Bradford-XXX		eSTOL	154,803	187,872	82.4%	0.32	0.28
London-XXX		eSTOL	163,906	175,104	93.6%	0.24	0.39
Manchester/Liverpool-XXX		eSTOL	134,972	136,800	98.7%	0.28	0.21
Cornwall-XXX		eSTOL	96,730	87,552	110.5%	0.27	0.20
Wider Southampton-XXX		eSTOL	40,012	49,248	81.2%	0.30	0.21
London-XXX		eSTOL	54,761	49,248	111.2%	0.25	0.35
Leeds/Bradford-XXX		eSTOL	33,635	36,480	92.2%	0.35	0.25
Edinburgh-XXX		eSTOL	62,664	74,784	83.8%	0.26	0.34
Glasgow-XXX		eSTOL	74,879	74,784	100.1%	0.28	0.37
Bristol-XXX		eSTOL	30,906	36,480	84.7%	0.28	0.28
Norwich-XXX		eSTOL	58,231	62,016	93.9%	0.20	0.22
Peterborough-XXX		eVTOL	91,029	105,216	86.5%	0.27	0.50
Redcar-XXX		eSTOL	48,317	49,248	98.1%	0.27	0.25
Belfast-XXX		eVTOL	474,716	396,672	119.7%	0.38	0.23
Peterborough-XXX		eVTOL	110,673	115,968	95.4%	0.39	0.99
Pembrokeshire-XXX		eVTOL	226,150	258,816	87.4%	0.43	0.12
Inverness-XXX		eVTOL	161,617	184,704	87.5%	0.34	0.42
Sheffield-XXX		eVTOL	242,380	264,192	91.7%	0.41	0.64
Total	528881		2,620,193	2,708,160	96.8%		

Across the 20 routes, a total of 528,000 trips were undertaken during the study week, before being assessed using a bespoke approach to demand modelling. The method considers a shifting of some demand during the peak periods to account for a scheduling effect whereby, as passengers achieve more usable hours during their day, more are willing to shift their departure time.

Additionally, it is assumed that yield management techniques will be employed through a pricing mechanism to encourage a shift of some demand to lower, off-peak periods. For each route, a total weekly achievable demand is calculated. An iterative process of scheduling will then be completed to create an indicative OD schedule, resulting in a weekly capacity being identified. Once this schedule is expanded to cover a full year, the annual demand and capacity can be identified, as well as the resultant load factor (The number of seats sold as a percentage of the seats available for sale).

In many cases, a load factor of more than 100% is calculated - which is the lost custom due to the scheduling exercise, in that there is more demand than supply. Load factors of greater than 100% could be inferred to be an 'induced demand' caused by providing this new service. This is much like the induced demand for car traffic when an additional lane is constructed on a congested highway.

4. Carbon Emissions Savings

AAM offers an opportunity for passengers to switch from road to aviation modes of transport, which are less polluting. For this analysis, the estimated carbon emissions for electric aviation flights were derived using publicly available information from electric aircraft manufactures, and an estimation of the UK energy mix in 2024. This information is used to calculate the estimated carbon emissions associated with the potential flights on the 20 routes assessed. Using DfT estimates of average passengers per car and average carbon emissions per kilometre, the estimated carbon emissions from road trips were calculated. In taking the difference between car emissions and electric aviation emissions we have determined that, on an annual basis, approximately 9,000 tons of carbon emissions could be saved.

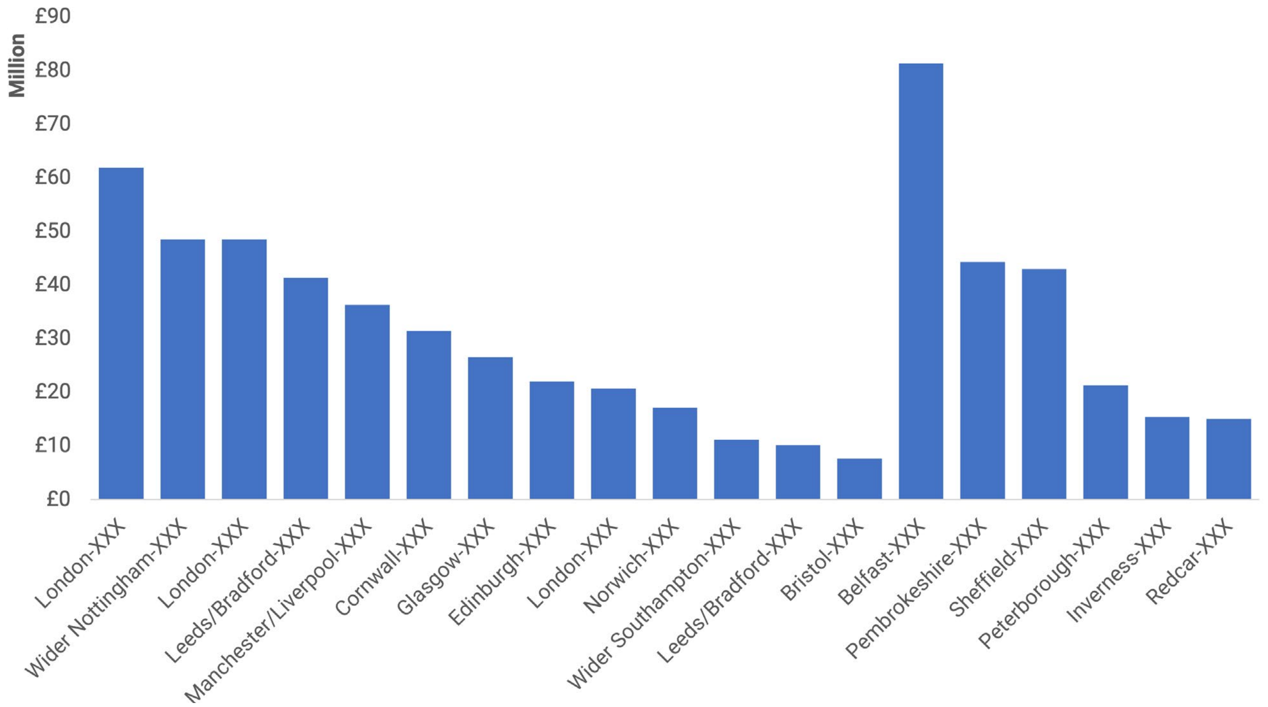
Route	Number of aircraft required	Total annual carbon emissions by AAM	Estimated annual carbon emissions saved by road pax switching	Estimated annual carbon emissions saved by rail pax switching	Total NET annual carbon savings
Wider Nottingham-XXX	6	3,751 kg	548,862 kg	210,702 kg	755,813 kg
London-XXX	8	5,135 kg	515,328 kg	345,747 kg	855,941 kg
Leeds/Bradford-XXX	6	4,366 kg	744,323 kg	71,370 kg	811,327 kg
London-XXX	10	9,586 kg	253,841 kg	631,972 kg	876,227 kg
Manchester/Liverpool-XXX	6	3,222 kg	624,494 kg	81,070 kg	702,342 kg
Cornwall-XXX	4	2,960 kg	806,644 kg	16,335 kg	820,020 kg
Wider Southampton-XXX	2	1,237 kg	236,430 kg	6,508 kg	241,701 kg
London-XXX	4	2,796 kg	149,813 kg	199,102 kg	346,120 kg
Leeds/Bradford-XXX	2	1,064 kg	193,941 kg	27,852 kg	220,729 kg
Edinburgh-XXX	4	3,086 kg	373,472 kg	67,970 kg	438,356 kg
Glasgow-XXX	4	3,164 kg	514,233 kg	92,240 kg	603,309 kg
Bristol-XXX	2	757 kg	114,967 kg	20,460 kg	134,670 kg
Norwich-XXX	4	1,712 kg	344,666 kg	30,356 kg	373,310 kg
Peterborough-XXX	16	9,277 kg	355,430 kg	22,551 kg	368,704 kg
Redcar-XXX	2	1,529 kg	214,459 kg	86,485 kg	299,415 kg
Belfast-XXX	44	23,662 kg	1,268,964 kg	5,366 kg	1,250,668 kg
Peterborough-XXX	14	7,992 kg	179,673 kg	93,003 kg	264,685 kg
Pembrokeshire-XXX	32	18,219 kg	696,680 kg	29,303 kg	707,764 kg
Inverness-XXX	24	13,960 kg	404,369 kg	95,202 kg	485,611 kg
Sheffield-XXX	30	16,445 kg	553,946 kg	70,798 kg	608,299 kg
Total	**224**	**133,918 kg**	**9,094,536 kg**	**2,204,393 kg**	**8,980,618 kg**

In this case, the analysis shows the estimated carbon savings by road users switching to AAM. It was calculated that rail users would omit around 2,200 tonnes less carbon emissions, although additional analysis would have to be undertaken to determine if there would be any impact on rail schedules as a result of competition for passengers. What is clear, however, is that on many of the routes assessed diesel trains provided services, thus there is a case to consider.

5. Revenue Estimation

Based upon a review of average fares per mile for business trips in the UK by air, including an uplift for early services aimed at business travellers given the scarcity of the service, and an assessment of similar rail fares, an average fare per mile was estimated and applied to the analysis. The analysis suggests that £704 million in fares could be earned by operators annually, which equates to approximately £3.1 million per aircraft per route on average. As previously stated, this estimation does not include any yield management techniques that would be employed by the operator which would likely increase the revenue generated. We would suggest that the revenue estimation in this analysis is not unreasonable for early years of operation.

Annual Operator Revenue Generation - Estimation
Analysis: EAMaven



6. Aircraft Utilisation

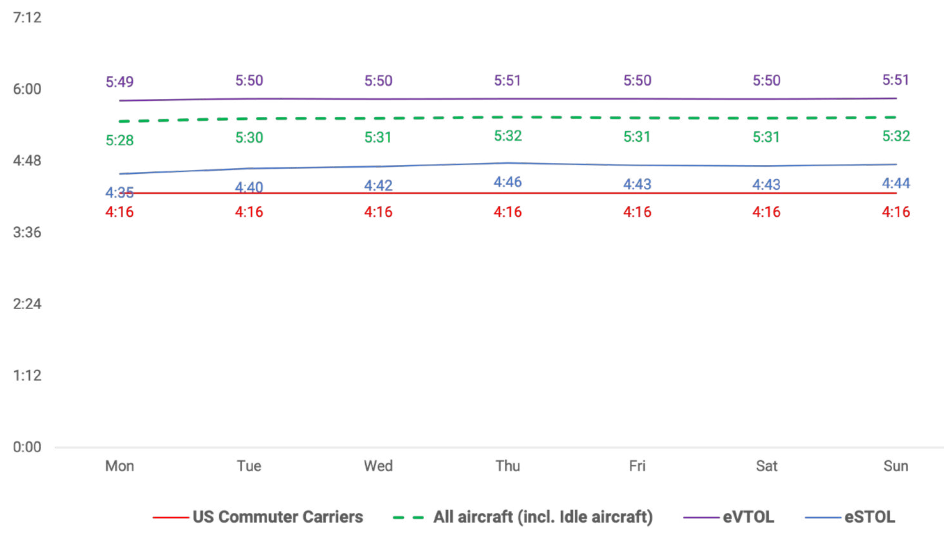
To better understand the daily utilisation, the following chart shows the average daily hours flown both eVTOL and eCTOL across a typical week. What is shown is that the demand is relatively even across the week, including the weekend. On other routes, analysis has shown that in certain OD pairs like London to Bournemouth exhibit high traffic volumes over the weekend, as residents of London travel to Bournemouth for the weekend to enjoy a beach holiday. This is a seasonal issue of course, but it gives rise to the potential repositioning of aircraft to service high weekend demand, in order to offset lower demand on other routes.

The notable difference is the higher rate of use for eVTOL vehicles, which is partially explained by their ability to serve smaller levels of demand, shorter turnaround times and relative operating speed.

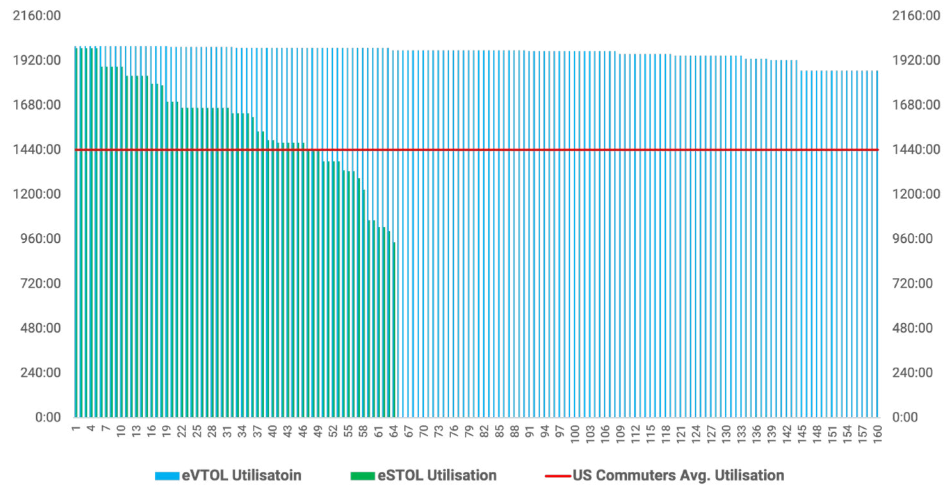
For comparison, an average aircraft utilisation for several US commuter carriers operating a combination of turboprops (DHC 8-400) and Small Regional Jets (ERJ-140, 145, CRJ 200) was calculated and shown to be 4:16, but it is averaged over the week for comparison purposes. Source (DOT Form 41).

The following chart illustrates the annual use for all aircraft with the average utilisation of US commuters shown for comparison.

All routes average daily aircraft utilisation (excl. deadhead flights)
Source: Scheduling, EAMaven analysis

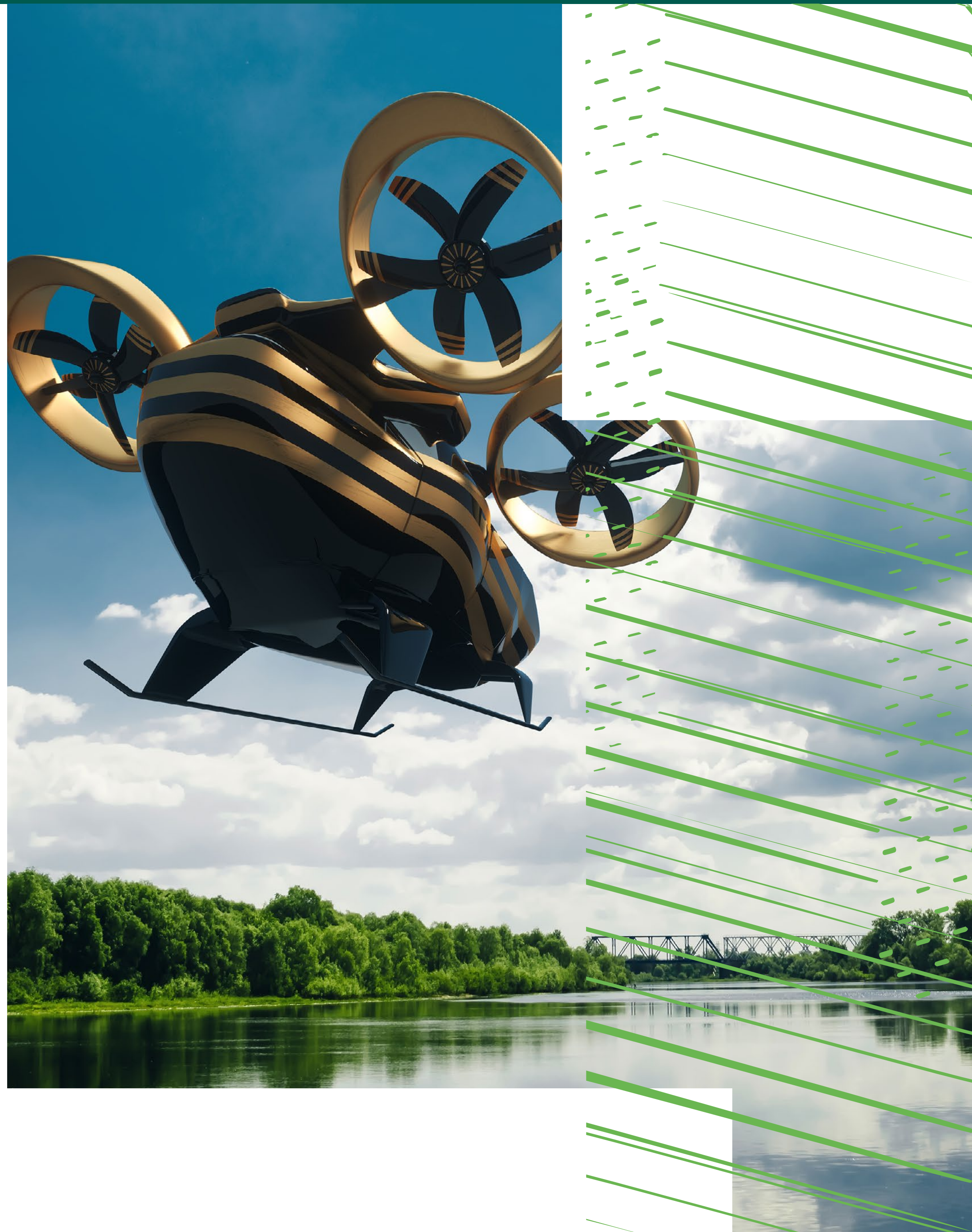


Aircraft utilisation per aircraft – all routes
Source: Scheduling, EAMaven analysis



The chart shows that on average eVTOL have a higher utilisation across the fleet in comparison to eCTOL aircraft. This is directly attributed to the smaller seat numbers offered on those shorter services. A wider analysis of the data held demonstrates that there is a 'sweet spot' in terms of range for specific eVTOL aircraft operation where market penetration, utilisation and revenue is maximised.

The assessment of the eCTOL aircraft shows a different story - which is a result of the routes chosen, average turnaround time and relative demand. It is likely that a number of the routes may not be chosen for operation, but other opportunities exist for them. However, a rational operator can redeploy some of these aircraft on other routes and/or restrict supply, thereby reducing demand and the number of aircraft needed. Alternatively, in some of these cases it may be that the economic benefit of direct services could meet the criteria for Public Service Obligation support, in that the economic benefit is significant in relation to Government economic objectives. Should the routes with less than 1,440h not be flown, then the average aircraft utilisation climbs to 1,713h per year.



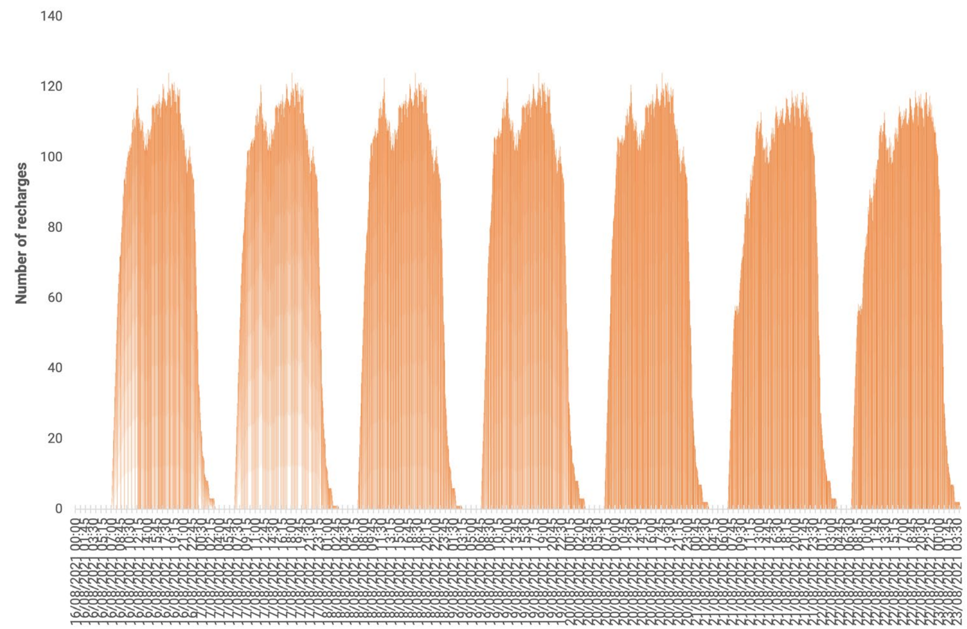
7. Infrastructure

The required landing infrastructure can also be determined, based on the schedule analysis. The chart below sets out the number of aircraft on stand for recharging purposes across the whole system throughout a week. This information gives us the peak number of stands required per airport/vertiport and an indication of the potential energy (hydrogen, electricity, other) required to power the flights.

This information can then be used to help mitigate against peak power requirements where the electric propulsion systems are using batteries as an energy source. For hydrogen-powered aircraft, the total volume of hydrogen can also be deduced to better understand the system requirements of electric aviation.

Additional insights can also be derived through the total volume of passengers that need to be processed per hour at each facility, thus aiding facility design. Building upon this information, entire financial and economic models can be built to help finance the system.

Summary of recharges
Source: Scheduling Analysis



8. Time Savings and Increased Economic Efficiency

Based upon the work undertaken, an assessment of the potential time savings and economic value of that time has been estimated. Across the routes, when assessing the time saved, the average for a single journey was about 2.4 hours - or 4.8 hours on a return flight. For an average working day of 8 hours, this represents 60% of a working day.

With reference to travel on public modes of transport in one week, a total of 67,000 hours could be saved. This is the equivalent of 8.3 years. For road users, the time savings is 21,000 hours or 2.4 years on a weekly basis. Combining the 2 modes means that, on a weekly basis, the time savings is equivalent to 10.7 years. On an annual basis, the potential time savings equates to approximately 528 years (note that the analysis assumes a 48-week year to account for disruptions due to external factors such as weather, delays and or technical issues).

Route	AAM Aircraft type	Car travel time savings (h)	Public transport time savings (pax/h)	Weekly total time saving cars (pax/h)	Weekly public transport time saving (pax/h)	Economic boost (lost travel time value – road)	Economic boost (lost travel time value – rail)
Wider Nottingham-XXX	eSTOL	1.64	0.97	3,930	1,726	£130,903	£29,018
Belfast-XXX	eVTOL	0.87	1.99	8,534	159	£284,255	£2,669
London-XXX	eSTOL	1.95	0.98	2,827	1,843	£94,179	£30,987
Leeds/Bradford-XXX	eSTOL	1.67	2.09	4,551	1,050	£151,607	£17,658
Peterborough-XXX	eVTOL	1.37	0.01	1,584	7	£52,779	£114
London-XXX	eSTOL	5.16	2.33	1,877	4,062	£62,514	£68,283
Manchester/Liverpool-XXX	eSTOL	2.05	3.05	4,601	1,714	£153,269	£28,805
Cornwall-XXX	eSTOL	2.94	4.46	5,711	338	£190,249	£5,676
Sheffield-XXX	eVTOL	1.18	0.46	4,784	463	£159,346	£7,782
Inverness-XXX	eVTOL	1.81	1.28	4,203	1,346	£140,000	£22,629
Pembrokeshire-XXX	eVTOL	1.19	6.61	5,199	2,335	£173,194	£39,243
Wider Southampton-XXX	eSTOL	2.06	3.51	1,634	148	£54,425	£2,480
London-XXX	eSTOL	4.95	2.88	1,022	1,524	£34,041	£25,624
Leeds/Bradford-XXX	eSTOL	1.66	2.36	908	358	£30,258	£6,012
Edinburgh-XXX	eSTOL	3.75	2.41	2,709	612	£90,237	£10,286
Glasgow-XXX	eSTOL	3.41	2.18	3,310	731	£110,262	£12,286
Bristol-XXX	eSTOL	2.05	2.05	983	337	£32,729	£5,664
Norwich-XXX	eSTOL	2.90	3.29	3,011	578	£100,303	£9,724
Peterborough-XXX	eVTOL	1.90	0.55	3,219	115	£107,221	£1,927
Redcar-XXX	eSTOL	4.48	5.00	2,538	2,199	£84,540	£36,973
			Total weekly	67,136	21,644	£2,236,313	£363,840
				88,781		£2,600,152	
			Total annually	3,222,546	1,038,923	£107,343,008	£17,464,301
				4,261,489		£124,807,310	

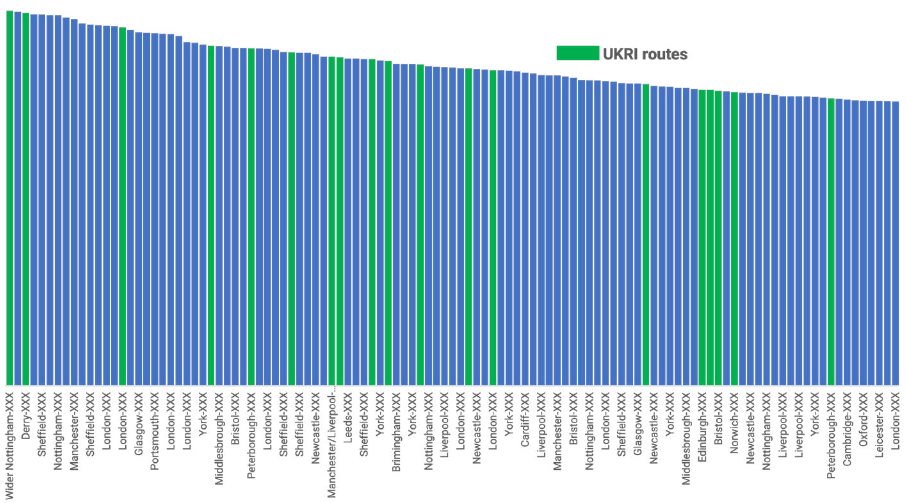
Using DfT WebTAG data, we have estimated that the annual economic value of the time savings is approximately £124 million for both modes of transport. In the case of road users, the value used is higher as drivers are less productive than on rail.

9. Overall Context

As stated, this assessment was based on 20 routes selected to be representative of several different potential routes. Not all routes may prove to be economically viable in isolation, but, with a rational operator approach to managing demand and networking of routes, more are likely to be viable.

To give context of the routes selected, we have charted the raw travel demand for 200 potential routes and highlighted the relative position of the routes selected in this analysis. Although the assessment looks both at eVTOL and eCTOL operations, it is reasonable to infer that each of these target cities could accommodate eCTOL operations either at the relevant airport, or at an airfield that has close proximity to the city.

UKRI 20 routes vs other UK routes weekly travels
Source: Mobility data, EAMaven analysis



10. Summary

The analysis is intended to provide an indication of the potential for AAM operations in the UK, providing information on number of aircraft needed, aircraft utilisation, revenue generation, time savings, economic stimulation, and carbon emissions savings.

This assessment shows the following key results:

- AAM is indeed economically viable and would provide a significant contribution to the economy, whilst also reducing carbon emissions of travel.
- On many of the northern routes, there are viable numbers of travellers given the anticipated lower cost of AAM services, such that the economic, environmental, and societal benefits, could be significant.
- With respect to the Union Connectivity Review, it demonstrates that AAM can and should play an important role in connecting the four nations through the provision of services not economically viable through building of new road or rail infrastructure.
- Commercially viable routes are available that could be developed through private investment in the vehicles and infrastructure, with no need for investment from the public.

11. Conclusions

Throughout our work on the study, it has been clear that there is not only a place for AAM services, but in many areas a real need. Each part of the research has shown a case for the introduction of these air services across a variety of UK regions to help support, and complement, existing transport infrastructure, with almost no exceptions.

This assessment focused predominantly on the economic scope for the introduction of this new technology, as this is often considered the bedrock on which its viability will be judged. While some more societal factors such as emissions and time saving are included, there is further opportunity to assess the wider social benefits of an AAM network by considering the benefits of greater connectivity and convenience in both rural and remote settings, and heavily-populated city-centre locations.

It's also important to remember there is still scope for substantially improving the results from this research further. Were a rational and efficiency-led operator to run an AAM network that is adaptive to the specific needs, demand and costs of designated routes to maximise their effectiveness, the case for supporting UK transport routes with AAM aircraft becomes ever more compelling.

12. Future Studies

EAMaven is currently producing the UK Regional Air Mobility Index which is an assessment of the potential number of routes between 40 regional airports in the UK. The study has assessed 1,058 potential routes and identified at least 390 routes that may be viable for AAM services. This report will be available in November 2022.

UK REGIONAL AIR MOBILITY INDEX – BIG NUMBERS — ALL ROUTES

40
REGIONAL AIRPORTS STUDIED*

5.05m
TRAVELLERS WEEKLY

242.2m
TRAVELLERS ANNUALLY***

1,058
ROUTES ASSESSED**

20%
ARE BUSINESS TRAVELLERS

80%
OF LEISURE/VFR TRAVELLERS

81.5%
OF TRAVELLERS BY CAR PRODUCING SIGNIFICANT CARBON EMISSIONS

* All routes from/to regional airports (and their respective catchment areas), based on weekly travel mobility data, annualised.
** Regional airports only, all possible airport pairs combinations analysed.
*** Routes with a regional airport as either origin or destination. To/from London routes excluded. Routes have a minimum distance of 60nm.

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UK REGIONAL AIR MOBILITY INDEX - BIG NUMBERS — TOP ROUTES

£8.95m
PER WEEK

£429.7m
PER YEAR**

Economic stimulation through increased productivity

310K HRS SAVED WEEKLY

14.9M HRS SAVED ANNUALLY

if switched to AAM***

3.8m
TRAVELLERS WEEKLY

182.4m
TRAVELLERS ANNUALLY***

On routes with minimum 10k travellers weekly

390
ROUTES IDENTIFIED*

With at least 2k travellers weekly – initial analysis suggests 128 routes in the UK with more than 10k travellers weekly

81.8%
OF TRAVELLERS BY CAR PRODUCING SIGNIFICANT CARBON EMISSIONS

25.6%
ARE BUSINESS TRAVELLERS

74.4%
OF LEISURE/VFR TRAVELLERS

* All routes from/to regional airports (and their respective catchment areas), based on weekly travels mobility data, annualised. Routes with a regional airport as either origin or destination. To/from London routes excluded. Routes with 60nm or more distances.

** Regional airports only, all possible airport pairs combinations analysed with routes up to 10k travellers weekly.

*** High-level assumption of a X% market share on top 128 routes. Time savings based on flight time vs car/rail travel time ratios. Economic stimulation based on the DfT WebTag data.

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