Appendix A – Options for addressing the cost of pilot training; Quantification Analysis Methodology

1. INTRODUCTION

1.1.1 As part of this study, a range of data sources were reviewed in an attempt to provide an indicative quantification of the potential scale of future pilot shortages. The different data sources are summarised in Table 1.

1.1.2 Whilst these data sources are regarded across the aviation industry as being authoritative, this analysis has not attempted to assess the accuracy of the data, and therefore the analysis should be viewed as providing estimates of the future demand and supply for pilots only, as implied by the industry forecasts.

1.1.3 This appendix provides further detail on the data sources and analysis undertaken. The key findings from the quantification are set out in section 3.5 of the main report, alongside the conclusions of the stakeholder engagement and literature review.

Table 1. Summary of demand and supply data sources

MODEL NUMBER	PILOT TYPE	DATASET FOCUS	DATASET(S)
1	Airline pilots	UK commercial fleet growth, as a proportion of industry forecasts (demand)	• Airbus' 2022 Global Market Forecast • Oliver Wyman's 2021 Global Fleet Forecast
2	Airline pilots	UK commercial fleet growth, based on historical airline fleet data (demand)	• CAA's UK Airline data, Table 1.11.2 • DfT Aviation Statistics AVI0203
3	Airline pilots	UK commercial pilot demand, as a proportion of worldwide industry forecasts (demand)	• Boeing's 2022 Pilot and Technician Outlook • Oliver Wyman's 2021 Pilot Forecast • CAE Inc.'s 2020 Pilot Demand Outlook
4	Business Aviation and Air Taxi pilots	Business Aviation + Air Taxi Pilot demand inferred from historical aircraft movement data (demand)	• CAA's UK Airport data, Table 3.1 • CAE Inc.'s 2020 Pilot Demand Outlook
5	Regional pilots	Regional pilot demand estimated from historical UK fleet data (demand)	• CAA's UK Airline data, Table 1.11.2
6	Commercial fixed-wing pilots (Airline, Biz + Air Taxi)	ATPL(A) licence issuance in the UK, based on historical data (supply)	• CAA's Pilot Licence holder statistics dataset
7	Commercial fixed-wing pilots (Airline, Biz + Air Taxi)	UK commercial pilot supply, as a proportion of worldwide forecasts (supply)	• Oliver Wyman's 2021 Pilot Forecast
8	Commercial Rotary pilots	Rotary Pilot demand inferred from historical aircraft movement data (demand)	• CAA's UK Airport data, Table 19
9	Commercial Rotary pilots	Rotary pilot supply via historical ATPL(H) + CPL(H) licence issuance (supply)	• CAA's Pilot Licence holder statistics dataset

2. GENERAL ANALYSIS APPROACH

2.1.1 In total, nine models (six Demand and three relating to Supply) were developed across two segments, 'Fixed wing' and 'Rotary' (see Table 1). The results of these models were compared to observe if they generated a consistent set of values for commercial pilot supply and demand, resulting in an estimate for the future shortage/surplus in 2026, 2031, and 2041.

2.1.2 In general, we have not made any explicit provision for the following in our analysis:

- Military conversions[1]; and
- The emergence of autonomous technologies.

2.1.3 Table 2 outlines the assumptions made during analysis.

Table 2. Index of Assumptions and relevant models

ASSUMPTION NUMBER	ASSUMPTION	DESCRIPTION	RELEVANT MODELS
1	UK percentage of European commercial aircraft fleet	UK holds ~17% of the European commercial aircraft fleet	• Model 1 – Fleet demand via industry forecasts
2	Pilot/Aircraft Ratio for UK Airlines	UK airlines employ 14 pilots per aircraft Regional airlines employ 12 pilots per aircraft	• Model 1 – Fleet demand via industry forecasts • Model 2 – Fleet demand via historic data
3	UK % of global pilot population	UK share of global pilot population = 4.3%	• Model 3 – Pilot demand via industry forecasts • Model 4 – Commercial Pilot demand via historical aircraft movement data • Model 7 – Pilot supply via industry forecasts
4	Attrition/Retirement rate of pilots	Annual supply of pilots decreases by 3.8%	• Model 3 – Pilot demand via industry forecasts • Model 6 - Pilot supply via historical licence issuance
5	Pilots required for X no. of aircraft movements	Aircrafts make 392 movements per annum Pilots required per aircraft: Business Aviation – 7.5 Air Taxi – 5	• Model 4 – Commercial Pilot demand via historical aircraft movement data
6	Pilot Employment rate	ATPL Pilot employment = 100% (all active pilots can contribute to supply) CPL Pilot employment = 55% (to account for commercial pilots in non-transport roles)	• Model 6 - Pilot supply via historical licence issuance
7	Pilots required per Rotary aircraft	Pilots required per Rotary Aircraft: 4.5	• Model 8 – Rotary pilot demand via historical aircraft movement data

[1] This is because the UK does not use military training as an explicit pathway to create commercial pilots, and the annual supply of military transfers is anticipated to be no more than 30-50 pilots per year. Of these, some will remain as instructors/non-flying positions in the RAF, others will take up alternative careers, and some may remain in aviation but not for commercial airlines.

3. FIXED-WING PILOTS

3.1 Model Details

3.1.1 In this report, 'Fixed-wing' refers to pilots that are qualified for:

- Airline Transportation (e.g. LCC, Long-haul, Freighters);
- Business Aviation;
- Air Taxi services; and
- Regional Airline Transportation (small aircraft, <100 passengers).

3.1.2 Due to the nature of how the underlying datasets are constructed, to assess overall commercial fixed-wing pilot demand against supply, demand analyses have been conducted separately for 'Airline' pilots, 'Business Aviation and Air Taxi' pilots, and for 'Regional' pilots respectively[2]. Models 1 – 3 in this Appendix therefore cover demand for 'Airline' pilots (flying aircraft >100 passengers/10t payload capacity) demand; Model 4 covers 'Business Aviation and Air Taxi' pilot demand; and Model 5 covers 'Regional' pilot demand (flying aircraft <100 passengers, and not belonging to Air Taxi or Business Aviation services). Together, these three categories cover the full breadth of commercial fixed-wing aircraft types recorded under CAA's 'Airline' data (Table 1.11.2) and by aggregating them, we get an overall demand metric covering the total workforce of qualified commercial transport pilots, to consider alongside the supply estimates which are only provided in that form.

Model 1 – Airline Pilot Demand via Industry forecasts of European Commercial Airline Fleet

3.1.3 Model 1 used industry forecasts for Europe's commercial aircraft fleet to estimate airline pilot demand. This is a robust approach to estimating pilot demand, because as both Valenta[3] and CAE Inc[4] argue, pilot demand is primarily driven by the size of the active fleet.

3.1.4 The following industry forecasts were used:

- Airbus' 2022 Global Market Forecast; and
- Oliver Wyman's 2021 Global Fleet Forecast.

3.1.5 These industrial forecasts are specifically concerned with commercial airline transportation and as such, the demand data obtained from these are for commercial aircraft >100 passengers or >10t payload capacity. Therefore, this model does not consider demand for regional commercial pilots flying aircraft with a seat capacity of less than 100 passengers. This condition is consistent across all three of the 'Airline' Pilot demand models (Models 1 – 3), and is the reason why an independent 'Regional' airline demand assessment (Model 5) was developed.

3.1.6 The size of the UK fleet was estimated as a proportion of forecasts for Europe, using the following assumptions:

- The UK holds ~17% of the European commercial airline fleet (Assumption 1)*;*
- UK airlines employ 14 pilots per aircraft (Assumption 2).

[2] Note that 'regional' refers to regional airline (servicing UK to UK routes) pilots whereas the 'airline' category considers international airline activities (travelling into/out of UK)

[3] V. Valenta, "Effects of Airline Industry Growth on Pilot Training," MAD - Magazine of Aviation Development, vol. 6, no. 4, pp. 52–56, Oct. 2018, doi: 10.14311/mad.2018.04.06.

[4] CAE Inc, "Airline and Business Jet Pilot Demand Outlook 10-year view 2020 Update," 2020. [Online]. Available: https://www.cae.com/news-events/press-releases/cae-releases-2020-2029-pilot-demand-outlook

3.1.7 Assumption 1 was calculated by comparing the size of the UK's commercial airline fleet (Table 1.11.2)[5] against the mean value of Airbus'[6] and Oliver Wyman's[7] European airline fleet estimates between 2015 – 2019. The historical trend of this percentage is shown in the figure below:

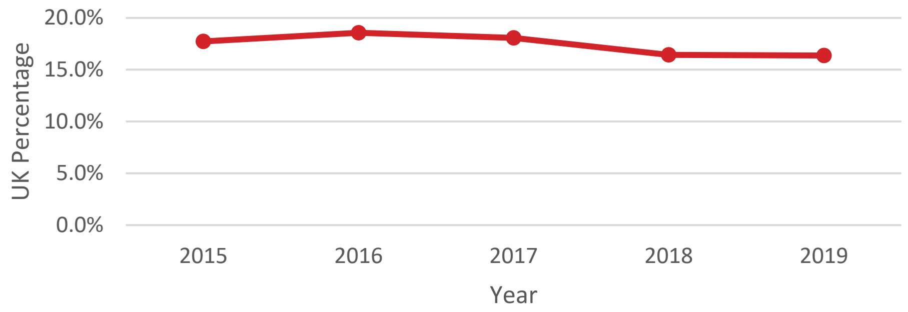


Figure 1. Estimate of UK percentage of European commercial airline fleet used for Assumption 1

3.1.8 On average, across this period the UK percentage of the European commercial aircraft fleet was 17% which was taken as the value used in Assumption 1. It is worth noting that of the CAA's UK commercial fleet dataset, only aircraft exceeding 100 passengers/10t payload capacity were considered to remain consistent with the condition (described in 3.1.5) of the Airline models. Additionally, the underlying industrial datasets for this model do not include Business Aviation, Rotary or Air Taxi services. To account for these exclusions, the demand for Business Aviation and Air Taxi services, and Regional Airlines have been modelled separately (see Models 4 and 5).

3.1.9 Assumption 2 was established using DfT data to form a ratio of pilot employment (AVI0203)[8] to UK airline fleet sizes[5].

Table 3. Assumption 2 calculations

MEASURE	VALUE
UK airline pilot employment – DfT (2019)	13,320 pilots
UK commercial airline fleet – CAA (2019)	920 aircraft
Pilot:aircraft ratio	**14 pilots/aircraft[9]**

3.1.10 If fleets will have a mix of narrow and wide-body aircraft, the pilot-aircraft ratio calculated above is within the boundaries of CAE Inc's estimates[4] that on average, 11 pilots are employed per narrow-body aircraft, and 17 pilots per wide-body aircraft. It is assumed for our subsequent modelling analysis that this ratio remains constant.

[5] Civil Aviation Authority, "UK airline data 2021," 2021. https://www.caa.co.uk/data-and-analysis/uk-aviation-market/airlines/uk-airline-data/uk-airline-data-2021/annual-2021/

[6] S. Shparberg and B. Lange, "Global Market Forecast 2022," 2022. [Online]. Available: https://www.airbus.com/en/products-services/commercial-aircraft/market/global-market-forecast

[7] T. Cooper, I. Reagan, C. Porter, and C. Franzoni, "Global Fleet and MRO Market Forecast 2021-2031," 2021. [Online]. Available: https://www.oliverwyman.com/our-expertise/insights/2021/jan/global-fleet-and-mro-market-forecast-2021-2031.html

[8] Department for Transport, "Worldwide Employment by UK registered airlines 2010-2020," 2020. [Online]. Available: https://www.gov.uk/government/statistical-data-sets/aviation-statistics-data-tables-avi

[9] The value is achieved by dividing 13,320 pilots by 920 aircraft and rounding.

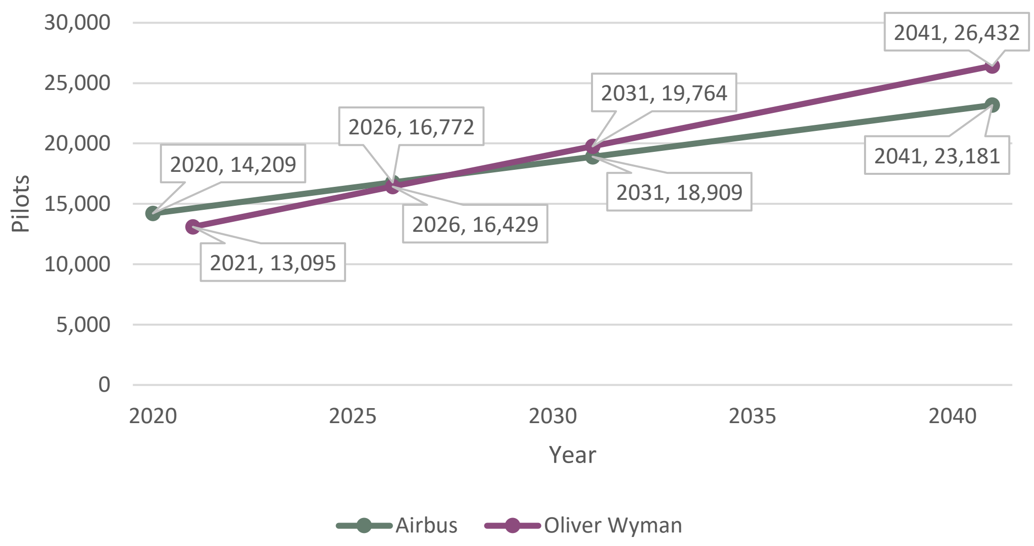
3.1.11 To obtain the results of Model 1, the UK's commercial airline fleet was estimated from Oliver Wyman's and Airbus' industrial forecasts as follows:

$$UK\ fleet\ estimate = Euro\ fleet\ size * UK\%\ of\ Euro\ fleet$$

3.1.12 Using this, an estimate of the demand for airline pilots then obtained:

$$UK\ Airline\ pilot\ demand = UK\ fleet\ estimate * Pilot\!:\!Aircraft\ ratio$$

3.1.13 The chart and table below presents the airline pilot demand forecast derived from Model 1.



AIRLINE PILOT DEMAND	2021 (2020)	2026	2031	2041
Oliver Wyman estimate	13,095	16,429	19,764	26,432
Airbus estimate	14,209*	16,772	18,909	23,181

Figure 2. UK Commercial Pilot demand forecasted from Model 1. Airbus baseline 2020, OW baseline 2021

Model 2 – Airline Pilot Demand via Historic Data of UK Commercial Airline Fleet

3.1.14 This model also uses aircraft fleet growth but instead relies on historical data for its forecast, using:

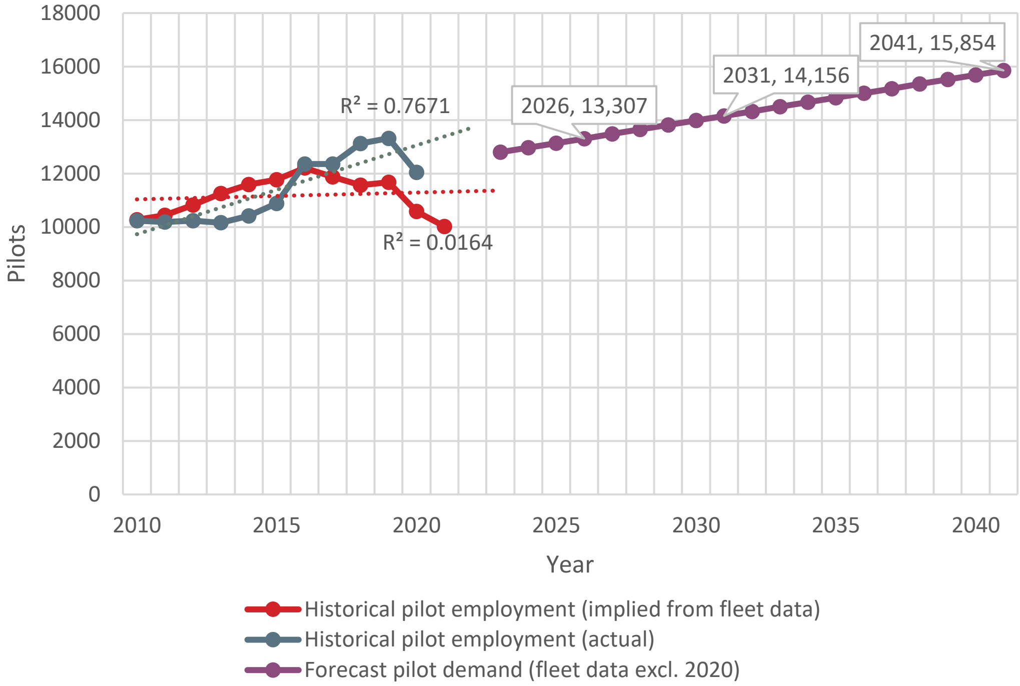
- CAA's UK Airline data, Table 1.11.2; and
- DfT Aviation Statistics AVI0203.

3.1.15 The fleet sizes of individual UK airlines were recorded from 2009 – 2021[5], and a linear regression forecast was conducted to estimate whether pilot demand could be inferred by extrapolating historical pilot employment. The decision to model this data linearly was taken because the industry forecasts from Model 1 predict demand to grow at a steady rate.

3.1.16 The forecast excludes data from 2020 and 2021 (to negate the distorting effect that COVID-19 would have on the data and hence provides a 'Pre-pandemic' estimate reflecting normal commercial conditions). To maintain clarity and simplicity and avoid misleading results being generated by additional input assumptions about which there remains uncertainty, potential future economic and social impacts on demand (e.g. changing behaviours towards air travel, increased remote working) resulting from COVID are not considered.

3.1.17 The number of pilots required as a result of these fleet forecasts was then estimated using the pilot:aircraft ratio (Assumption 2 in Model 1 above).

3.1.18 The chart and table below present the findings from Model 2. As shown, the 'implied' and 'actual' historical employment do not follow a similar trend line which suggests that this forecast is not an accurate predictor of future expected demand. Additionally, the trendline plotted for the implied data is not strongly correlated, meaning that the data is not well modelled by a linear trend. The actual historical employment does show that pilot demand has increased gradually, bar the decline seen in 2020 due to the impact of COVID.



AIRLINE PILOT DEMAND	2021	2026	2031	2041
Estimate based on historical UK airline fleet size	12,458	13,307	13,987	15,854

Figure 3. UK Commercial Pilot demand forecasted from Model 2

Model 3 - Industry Forecasts of Airline Pilot Demand

3.1.19 In this model, an estimate of UK pilot demand was created from several industry forecasts, as follows:

- Boeing's 2022 Pilot and Technician Outlook[10];
- Oliver Wyman's 2021 Pilot Forecast[11]; and
- CAE Inc.'s 2020 Pilot Demand Outlook[4].

3.1.20 The UK's share of active pilots was estimated as a proportion of Worldwide statistics. Demand could then be inferred such that:

$$UK\ pilot\ demand = Global\ demand * UK\ \%\ of\ global\ pilot\ market$$

3.1.21 The proportion of UK to global demand was taken as 4.3% from CAE and DfT data (see Assumption 3 in Table 4). It was also assumed that this value remains constant into the future.

Table 4. Assumption 3 - UK share of global pilot market

MEASURE	VALUE
Active airline pilots worldwide (2017)[12]	290,000
Pilot employment by UK airlines (2017)[13]	12,354

3.1.22 The data from these various sources was not homogeneous and so several adjustments were made to present the data in a consistent format, as listed in the table below.

Table 5. Model 3 adjustments

SOURCE	DATA SOURCES + ADJUSTMENTS
Boeing	2022 baseline figure from OW used (due to absence of Boeing data) 2041 global demand for 'new' pilots was converted to 'total' global pilot demand by comparing to the 2022 baseline estimate + applying an annual retirement/attrition factor.
Oliver Wyman	2021 to 2029 figures quoted direct from source.
CAE	2019 figure quoted direct from source. 2020 + 2021 figures estimated from 2020 Pilot Demand Outlook

3.1.23 Where required, an annual pilot attrition factor of 3.8% was applied (Assumption 4) so that the forecasts for 'new' pilot demand could be converted into the 'total' demand required by 2026, 2031, and 2041. This figure is quoted from CAE's 2020[4] estimate for annual pilot retirement rate.

3.1.24 Note that while Oliver Wyman's and CAE's datasets provided baseline values for pilot demand, the Boeing data did not, and so the Oliver Wyman figure was used for the Boeing dataset.

---

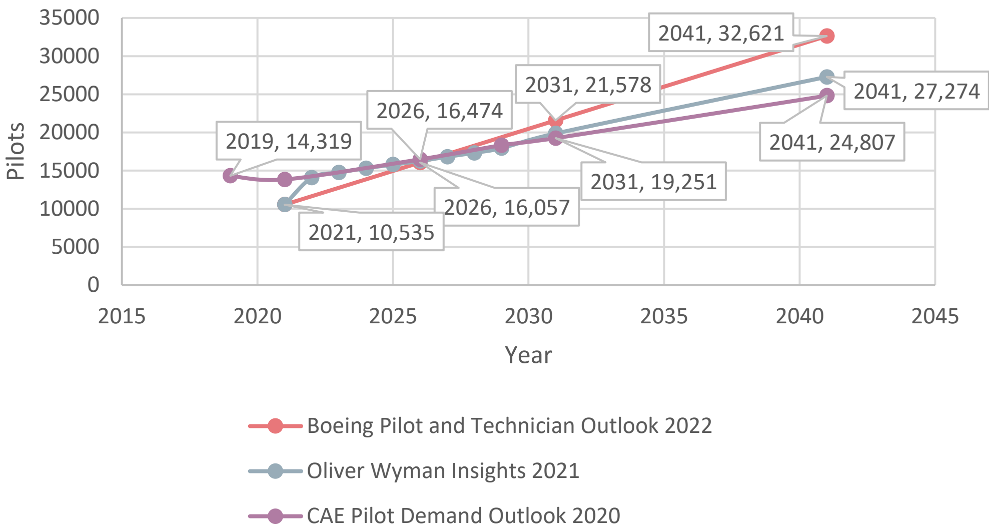
[10] Boeing, "Pilot and Technician Outlook 2022-41," 2021. [Online]. Available: https://www.boeing.com/commercial/market/pilot-technician-outlook/

[11] G. Murray, "After COVID-19, aviation faces a pilot shortage," 2021. [Online]. Available: https://www.oliverwyman.com/our-expertise/insights/2021/mar/after-covid-19-aviation-faces-a-pilot-shortage.html

[12] CAE Inc, "Airline Pilot Demand Outlook 2018," 2018. [Online]. Available: https://www.cae.com/news-events/press-releases/cae-releases-its-first-business-jet-pilot-demand-outlook-50000-new-business-jet-pilots-required-over-the-next-10-years

[13] Department for Transport, "Worldwide Employment by UK registered airlines 2010-2020," 2020. [Online]. Available: https://www.gov.uk/government/statistical-data-sets/aviation-statistics-data-tables-avi

3.1.25 Finally, given the different timeframes which these forecasts consider, the data was extrapolated (where necessary) to 2041 using linear regression, so that a common comparison could be drawn between each forecast. The chart and table in Figure 4 presents the findings from Model 3.



AIRLINE PILOT DEMAND	2021	2026	2031	2041
Boeing estimate	10,535	16,057	21,578	32,621
Oliver Wyman estimate	10,535	16,254	19,864	27,274
CAE estimate	13,831	16,474	19,251	24,807

Figure 4. UK Commercial Pilot demand forecasted from Model 3

Model 4 – Business Aviation + Air Taxi Pilot demand inferred from historical aircraft movement data

3.1.26 A mix of historical data, and industry forecast estimates were used to find the number of pilots needed to complete the annual transport movements relating to Business Aviation and Air Taxi services:

- CAA's UK Airport data, Table 3.1; and
- CAE Inc.'s 2020 Pilot Demand Outlook.

3.1.27 The rationale behind these assumptions is provided in Table 6 and Table 7 below (Assumption 5). For the business aviation category, an additional forecast was conducted using CAE's 2020 global Business Aviation pilot demand data[4], and applying Assumption 3.

Table 6. Assumption 5 – Estimate for yearly aircraft movements

MEASURE	VALUE	RATIONALE
Movements per aircraft per day	2	One morning + afternoon aircraft movement
Aircraft operating rate (days per week)	4	Aircraft will not be in constant operation - broad estimate for how many movements aircraft is likely to make per week.
Aircraft utilisation rate (weeks per year)	49	Assumes aircraft are out of commission for 3 weeks a year (e.g. maintenance)
Movements per aircraft per year	392	

Table 7. Assumption 5 cont. – Pilots required per Aircraft

MEASURE	PILOTS PER AIRCRAFT	RATIONALE
Business Aviation	7.5	Assumes crews consist of 2.5 pilots[14], and 3 crews are required (2 8 hour blocks + a rest crew) to operate an aircraft in a given week
Air Taxi	5	Assumes crews consist of 2.5 pilots, and 2 crews are required to operate an aircraft in a given week

3.1.28 To obtain the results based on historical data, the size of the UK's Business Aviation + Air Taxi aircraft fleet was estimated based on recorded Air Traffic Movements such that:

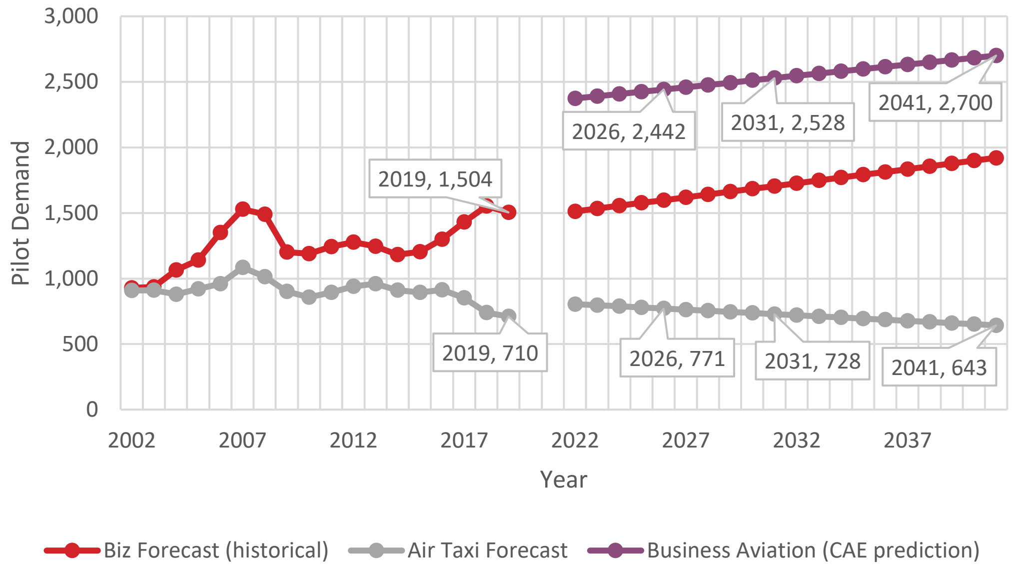
$$Required\ fleet\ size = \frac{ATMs}{Movements\ per\ aircraft\ per\ year}$$

From this, an estimate for total pilot demand was achieved:

$$Pilots\ demanded = \frac{Required\ fleet\ size}{Pilots\ per\ aircraft}$$

3.1.29 To obtain results from CAE's 2029 forecast, the data was linearly interpolated between 2019 and 2029 to obtain an estimate for 2026, and then extrapolated to obtain estimates for 2031 and 2041. The chart and table in Figure 5 below presents the airline pilot demand forecasts derived from Model 4.

[14] Business Aviation differs from Commercial transportation in that to meet the requirements of businesses, firms need to provide an 'on-demand' service. To reflect this, an estimate of 2.5 pilots per aircraft was used to consider that Business Aviation firms will need an excess supply of pilots to be able to react quickly to business requirements.



PILOT DEMAND	2021	2026	2031	2041
Business Aviation historical estimate	1,100	1,598	1,705	1,920
Business Aviation CAE estimate	2,356	2,442	2,528	2,700
Air Taxi estimate	641	771	728	643

Figure 5. Historical + forecasted pilot demand for Business Aviation and Air Taxi services

Model 5 – Regional Pilot demand estimated from historical UK fleet data

3.1.30 In the absence of industrial forecasts for this category, CAA fleet data[15] was used to estimate the historical level of demand for regional airline pilots.

3.1.31 Aircraft which held <100 passengers /10t payload capacity and were registered to Regional Airlines were included in the fleet count.

3.1.32 To estimate pilot demand, a pilot:aircraft ratio of 12 (Assumption 2) was applied to the fleet count:

$$UK\ Regional\ pilot\ demand = UK\ Regional\ fleet\ count * Pilot\!:\!Aircraft\ ratio$$

3.1.33 This ratio assumes crews consist of 2 pilots, and 6 crews are required to operate aircraft in a given week. The estimate of historical pilot demand that this produces is shown below in Figure 6. It can be seen that up to 2019, demand remained roughly constant, fluctuating between 2000 – 2500 pilots per year. However, during 2020 and 2021 the demand for pilots decreases significantly. This is likely due to COVID-19 and the collapse of Flybe and Stobart Air causing a sell-off of aircraft holdings by regional airlines.

[15] CAA's UK Airline data, Table 1.11.2

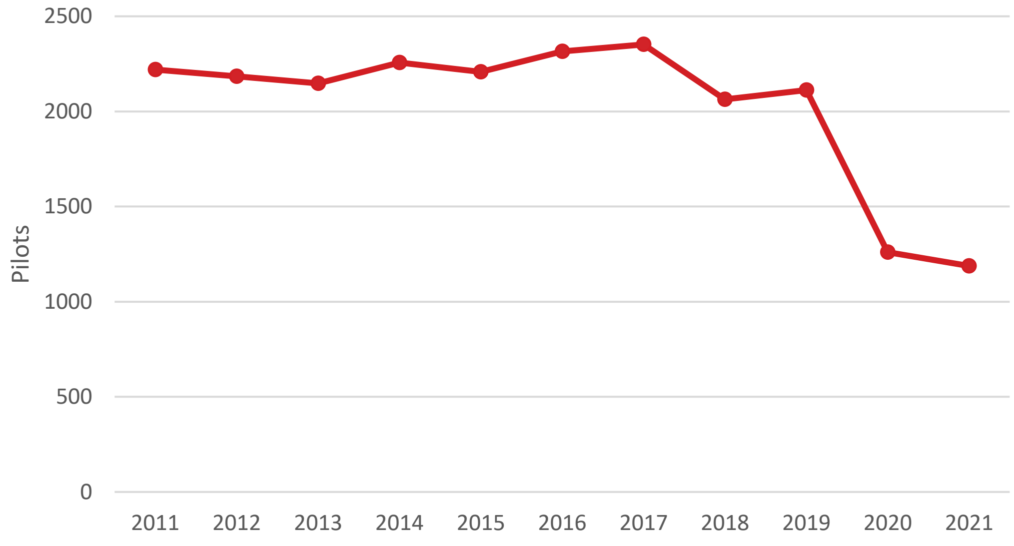
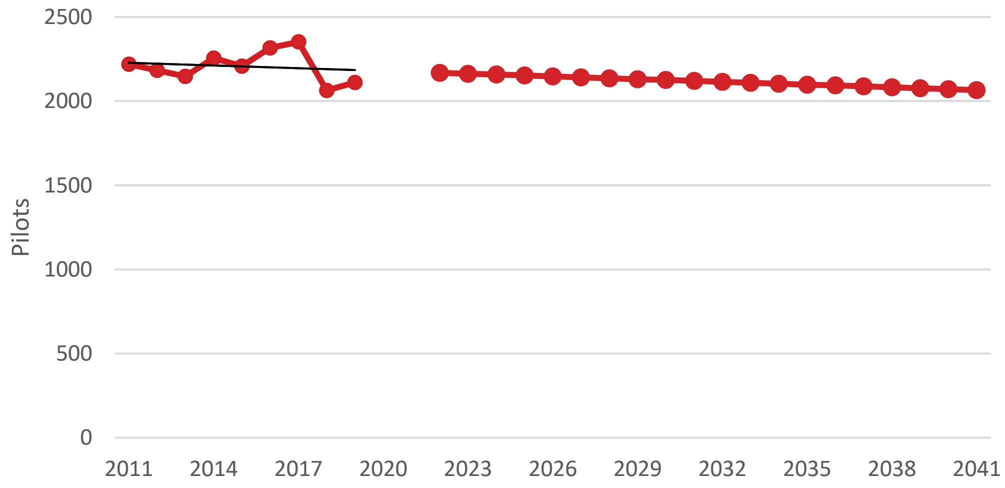


Figure 6. Estimated demand for regional airline pilots, 2011 – 2021

3.1.34 To estimate the future demand for regional pilots, the results from 2020 and 2021 were excluded, due to the significant skew these data points introduce. At this point in time, no 2022 data on aircraft holdings or industrial forecasts of regional pilot requirements could be sourced. Therefore, it is difficult to predict whether there will be a lasting impact caused by COVID on regional pilot demand. The figure and table below shows the future prediction of demand assuming that regional aircraft fleet holdings return to pre-pandemic levels.



REGIONAL PILOT DEMAND	2021	2026	2031	2041
Historical estimate	2,174	2,147	2,120	2,066

Figure 7. Forecast of regional airline pilot demand (pre-COVID)

Model 6 – Commercial Transport Pilot Supply via Historical Licence Issuance

3.1.35 In this model, historical CAA data was used to forecast the number of valid ATPL(A) + CPL(A) licence holders[16], as a measure of the UK's available commercial pilot supply. By observing the number of licences that were issued per annum (between 2004 and 2018), an attempt was made to forecast the future levels of supply using linear regression.

[16] Civil Aviation Authority, "Pilot licence holders by age and sex," 2018. https://www.caa.co.uk/data-and-analysis/approved-persons-and-organisations/personnel-licensing-statistics/pilot-licence-holders-by-age-and-sex/

3.1.36 The historical supply levels are shown in Figure 8. Trendlines fitted to the two categories produced correlation coefficients of R^2 = 0.4642 and R^2 = 0.322 (for ATPL(A) and CPL(A) respectively). This indicated that the trendlines were poor predictors of future pilot licence supply, which may be in part due to a lack of data available for 2006 – 2008, 2009 – 2011, and 2018-2021.

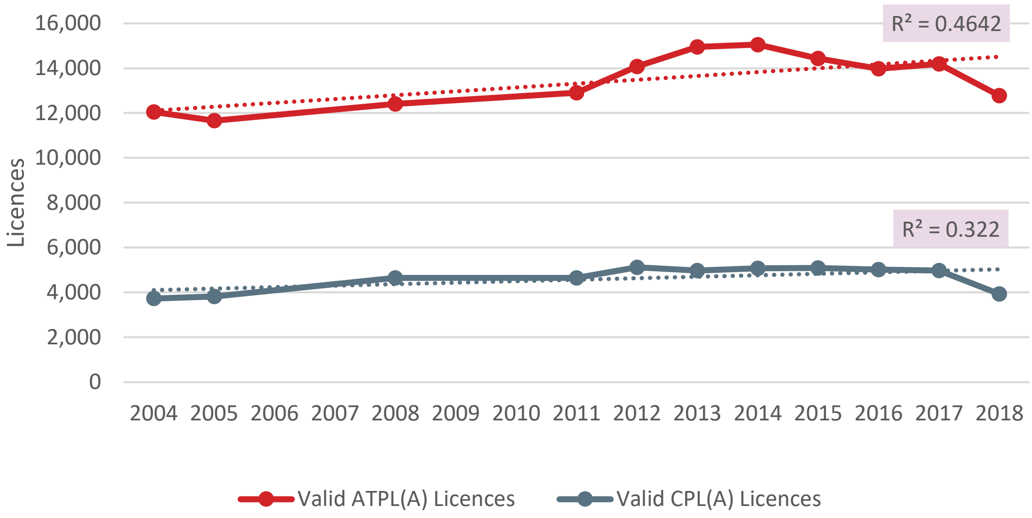


Figure 8. Historical record of valid ATPL(A) licences (2004 – 2018)

3.1.37 Due to the challenges described above, a second approach to estimating commercial pilot supply was developed using the number of new licences issued per annum (between 1998 – 2018) [17] as an indicator for pilot supply growth. However, there were no clear trends (growth or decline) for either licence type. Rather, the annual values fluctuated between 800 – 1,400 per annum (for ATPL) and 625 – 1,350 (for CPL).

3.1.38 To draw a forecast for the future total licence holder population, therefore, a 3-point estimate was used in conjunction with an attrition factor to model the inflow and outflow of pilot supply. The 3-point estimate for supply inflow assumes that the annual number of new licences issued is constant. An estimate was constructed for each licence type, and the three supply levels were taken as the mean, upper quartile, and lower quartile of new ATPL/CPL licences issued between 2008 – 2018[17], as shown in Table 7.

Table 8. Values used for annual supply of new pilots added to workforce

SUPPLY LEVEL (TAKEN FROM CAA DATA)	NEW PILOTS (PER ANNUM)
Upper Quartile of New ATPL licences (2008 – 2018)	1106
Lower Quartile of New ATPL licences (2008 – 2018)	814
Mean of New ATPL licences (2008 – 2018)	968
Upper Quartile of New CPL licences (2008 – 2018)	1287
Lower Quartile of New CPL licences (2008 – 2018)	932
Mean of New CPL licences (2008 – 2018)	1094

[17] Civil Aviation Authority, "Pilot licence transactions by type and rating," 2018. [Online]. Available: https://www.caa.co.uk/data-and-analysis/approved-persons-and-organisations/personnel-licensing-statistics/pilot-licence-transactions-by-type-and-rating/

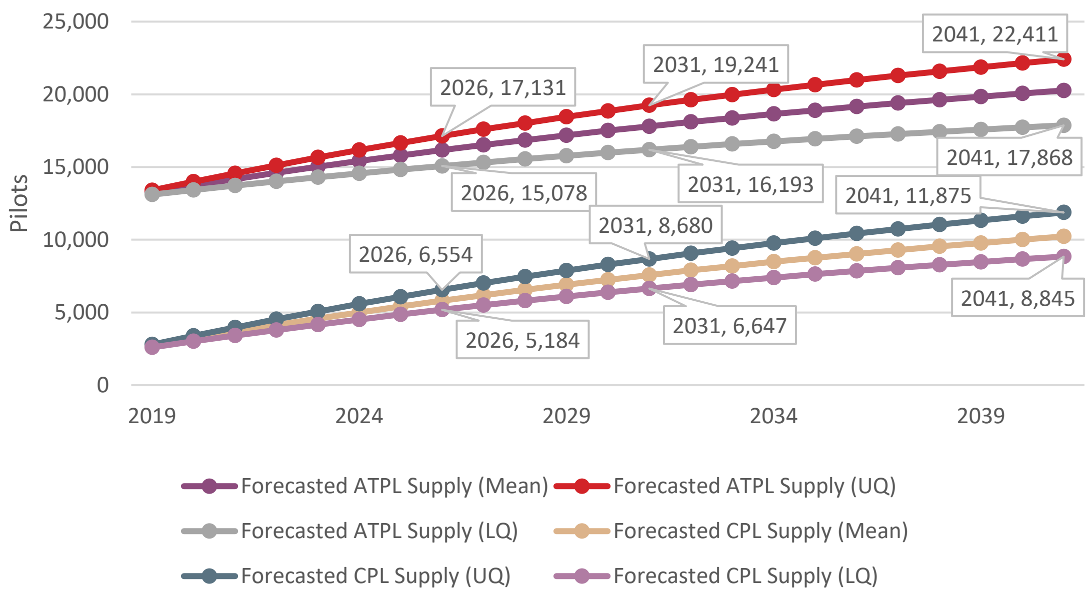
3.1.39 To model the supply outflow, the attrition rate from Model 3 (3.8% of pilot population, per annum) was reused to account for pilots leaving the workforce.

3.1.40 To calculate the final estimates of the future pilot supply, the following formula was applied:

$$Pilot\ Supply = Supply\ of\ previous\ year * (1 - Attrition\ rate) + New\ pilots$$

3.1.41 Note that because CPL licence can be hold for non-transportation pilot roles, it was assumed that 55% of CPL licence holders were employed in commercial transportation roles, and that ATPL employment rate was 100% (Assumption 6). EASA/JAR and UK license figures were also aggregated.

3.1.42 Because of Assumption 6, the model does not account for ATPL pilot unemployment or ATPL licence holders who are employed in other industries/non-pilot roles. This model also does not account for pilots who qualify in the UK but then move to work abroad, which may be as high as 20% of new qualifiers[18]. The chart and table below presents the findings from Model 6.



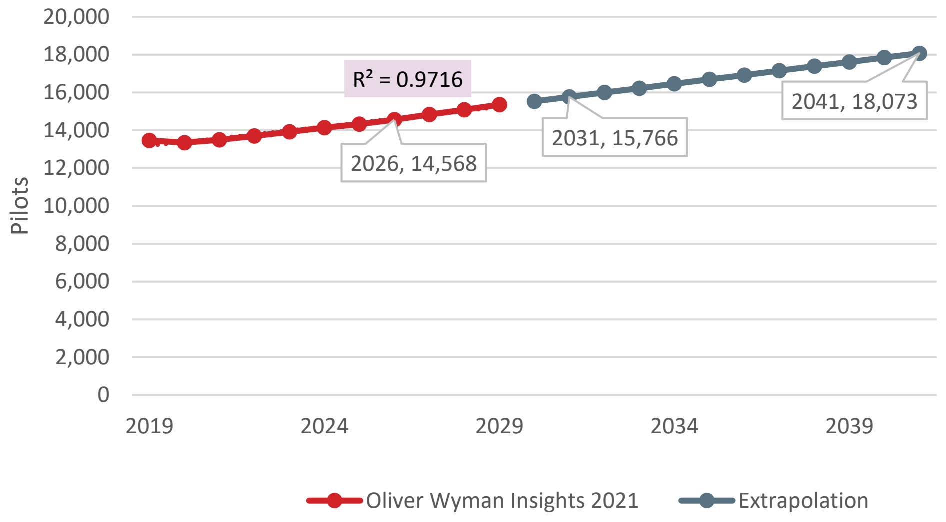
COMMERCIAL PILOT SUPPLY	2021	2026	2031	2041
ATPL + CPL supply (upper estimate)	18,543	23,685	27,921	34,286
ATPL + CPL supply (lower estimate)	17,134	20,262	22,840	26,712

Figure 9. UK Commercial Pilot Supply forecast from Model

[18] A. O'Loughlin, "Pilot shortage looms but UK and European commercial pilot licence issues are down," 2016. https://www.fta-global.com/fta-news/pilot-shortage-looms-but-uk-and-european-commercial-pilot-licence-issues-are-down

Model 7 – Commercial Transport Pilot Supply via Industry Forecast

3.1.43 This model uses Oliver Wyman's 2019 – 2029 forecast of global pilot supply[11] as a benchmark to produce a UK projection. The data was extrapolated from 2029 – 2041 using linear regression and then the UK share of the global pilot market (Assumption 3) was applied to the forecast. This assumes that extrapolating the Oliver Wyman data to 2041 is valid and that the UK's share of the global market remains constant. These are reasonable assumptions to produce a broad indication of potential future supply given the relatively short timeframe that is considered (up to 2041). Figure 10 below presents the findings from Model 7.



COMMERCIAL PILOT SUPPLY	2021	2026	2031	2041
Oliver Wyman estimate	13,493	14,568	15,766	18,073

Figure 10. UK Commercial Pilot supply forecasted from Model 7

Summary of fixed-wing pilot demand and supply estimates

3.1.44 Table 9 summarises the fixed-wing pilot demand estimates, calculated from Models 1 – 7. The Aggregated fixed-wing pilot demand estimates are comprised by summing the largest/smallest values from each category (Airline, Biz, Air Taxi, and Regional) for the highest and lowest estimates of demand, respectively. These values are highlighted in red (when used in the highest demand total), green (for the lowest demand total) or blue (where the value is used in both). An estimate for the mean level of pilot demand is also shown. This is comprised of: Mean Airline demand + Mean Biz demand + Air Taxi demand + Regional demand.

3.1.45 This process is repeated for the pilot supply estimates shown in Table 10 below.

Table 9. Summary of fixed-wing pilot demand estimates

Airline Pilot Demand	2021	2026	2031	2041
Model 1 Oliver Wyman	13,095	16,429	19,764	26,432
Model 1 Airbus	**14,209**	**16,772**	**18,909**	**23,181**
Model 3 Boeing	10,535	**16,057**	**21,578**	**32,621**
Model 3 Oliver Wyman	**10,535**	16,254	19,864	27,274
Model 3 CAE	13,831	16,474	19,251	24,807
Biz Pilot + Air Taxi Pilot Demand	2021	2026	2031	2041
Model 4 Biz Av (historical)	**1,100**	**1,598**	**1,705**	**1,920**
Model 4 Biz Av (CAE)	**2,356**	**2,442**	**2,528**	**2,700**
Model 4 Air Taxi	**641**	**771**	**728**	**643**
Regional Pilot Demand	2021	2026	2031	2041
Model 5 historical	**1,188**	**2,147**	**2,120**	**2,066**
Aggregated fixed-wing pilot demand	2021	2026	2031	2041
Low estimate	**13,464**	**20,572**	**23,462**	**27,810**
Mean estimate	**15,998**	**21,335**	**24,838**	**31,882**
High estimate	**18,394**	**22,133**	**26,955**	**38,030**

Table 10. Summary of fixed-wing pilot supply estimates

Fixed-wing Pilot Supply	2021	2026	2031	2041
Model 6 CPL + ATPL upper estimate	**18,543**	**23,685**	**27,921**	**34,286**
Model 6 CPL + ATPL lower estimate	17,134	20,262	22,840	26,712
Oliver Wyman estimate	**13,493**	**14,568**	**15,766**	**18,073**
Aggregated fixed-wing pilot supply	2021	2026	2031	2041
Low estimate	**13,493**	**14,568**	**15,766**	**18,073**
Mean estimate	**16,390**	**19,505**	**22,175**	**26,357**
High estimate	**18,543**	**23,685**	**27,921**	**34,286**

3.2 Sensitivity Analysis

3.2.1 The results of this analysis are based on several estimates/assumptions which were formed due to a lack of first-hand data. The variables with the highest uncertainty of accuracy were selected for sensitivity testing to measure how changing their values affects the outputs of the model. In total, three variables were tested:

- UK % of European commercial aircraft fleet (Assumption 1); and
- UK % of global pilot population (Assumption 3); and
- Pilot Attrition/Retirement rate (Assumption 4).

3.2.2 The impact of each variable was tested individually by changing its value and comparing the change to the baseline values pilot shortage/surplus. Only one variable was changed at a time, and the other two variables were kept at their baseline values. The 'steps' that were used are shown below:

Table 11. Testing levels (min step and max step) used for each variable

VARIABLE	MEASURE	BASELINE	MIN STEP	MAX STEP
1	UK % of European commercial aircraft fleet	17%	15%	19%
2	UK % of global pilot population	4.3%	3.44%	5.16%
3	Pilot Attrition/Retirement rate	3.8%	3.04%	4.56%

3.2.3 Variable 1's range was inferred from the range of historical values that were recorded in Figure 1 – Estimate of UK % of European commercial airline fleet. For variables 2 and 3, the minimum and maximum levels assume the baseline figure varies by +- 20%. The results of this analysis are shown in the figures below. It can be seen in Figure 11 that changing Variable 1 did not have a significant effect on the final estimates for pilot surplus/deficit. The largest deviation from the baseline best-case to worst-case range of estimates was a 14.2% increase in 2031 (Baseline: -11,189 to 4,459 vs Min step: -11,189 to 6,683).

3.2.4 The effect of changing Variable 2 on the analysis output was more significant as shown in Figure 12. Testing the min step level had the greatest impact and had the effect of increasing the best-case surplus estimates by ~3,300 for 2026, 2031, and 2041. The minimum step level also impacted the worst-case deficit estimates. In the most extreme case, the 2041 estimate was reduced by 3,114 pilots. Despite these impacts, Figure 12 shows that the conclusions drawn from these range of estimates broadly remains the same – that a shortage of pilots will possibly emerge as soon as 2026.

3.2.5 Finally, the impact on pilot surplus/deficit of changing Variable 3 was observed and results are shown in Figure 13. These show that changing the retirement/attrition rate had minimal impact on the estimates for worst-case pilot deficit. This is not the case for the range of best-case surplus estimates, where there is a more noticeable impact on the results. In 2026, there is a minor impact on the surplus estimates (ranging from -764 to +852 additional pilots) but by 2041, this impact grows to adjust the surplus estimate by -2,994 to +3,398. Despite this, the distribution of results does not change dramatically, and the same broad conclusion of a possible future pilot shortage remains true.

3.2.6 Overall, this sensitivity analysis has shown that the outputs do vary as the input variables are changed. However, the overarching conclusion from the baseline estimates remains valid throughout, and in all cases it is shown that there is a possibility of a pilot shortage emerging between 2026 – 2041.

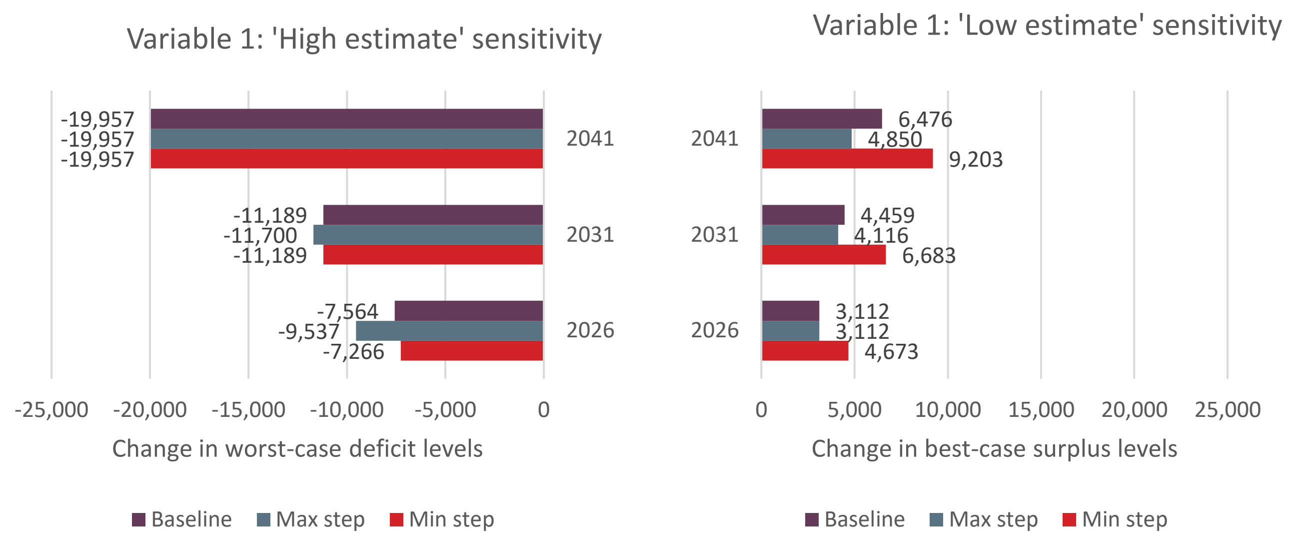


Figure 11. Variable 1 impact on 'high estimate' and 'low estimate' scenarios deficit/surplus results, compared to baseline estimate

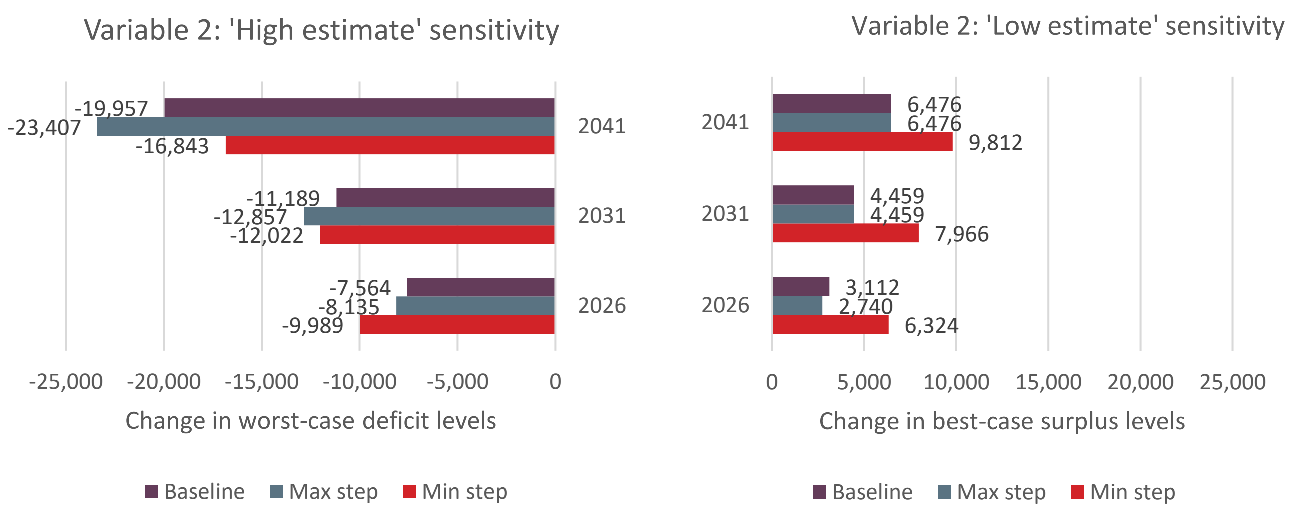


Figure 12. Variable 2 impact on 'high estimate' and 'low estimate' scenarios deficit/surplus results, compared to baseline estimate.

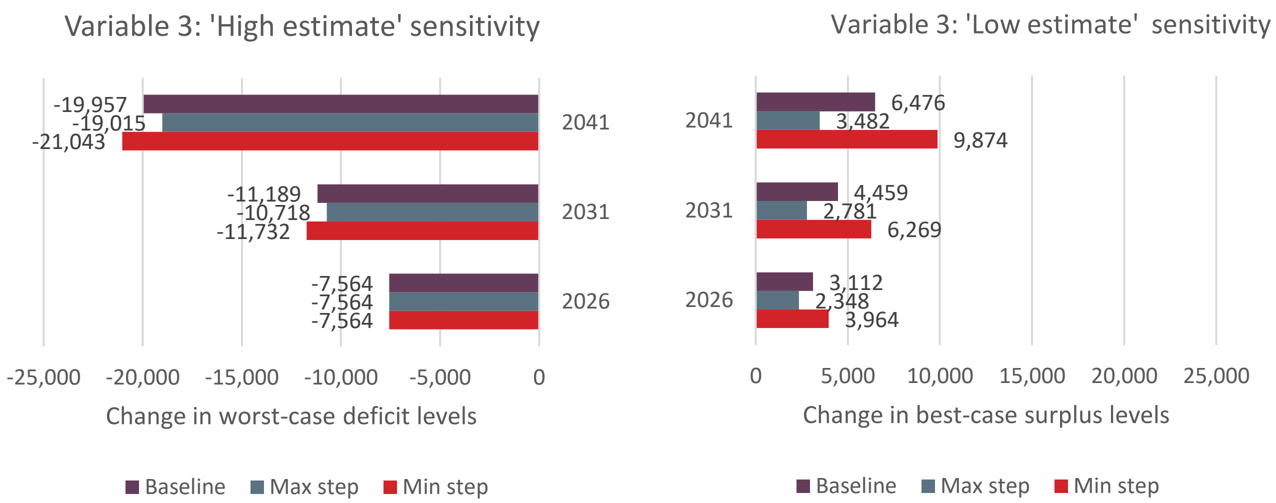


Figure 13. Variable 3 impact on 'high estimate' and 'low estimate' scenarios deficit/surplus results, compared to baseline estimate

4. ROTARY PILOTS

4.1.1 The demand and supply of Rotary pilots requires separate analysis to Fixed-wing pilots. To qualify as a helicopter pilot, a Helicopters Commercial Pilot Licence (CPL(H); '(H)' indicating helicopter) must be held, or a ATPL(H) to pilot multi-crew, multi-engine helicopters. Therefore, because of different licencing and training requirements Rotary demand/supply does not draw from the same pool as Fixed-wing and should be considered as a separate category.

4.2 Model Details

Model 8 – Rotary Pilot demand inferred from historical aircraft movement data

4.2.1 Using a similar approach to Model 4, an estimate from historical data[19] was used to find the number of pilots needed to complete the annual transport movements relating to Rotary services. The estimate number of aircraft movements from Assumption 5 was re-used, and an estimate for the number of Rotary pilots per aircraft was created, as shown below in Assumption 7.

Table 12. Assumption 7 – pilots required per Rotary aircraft

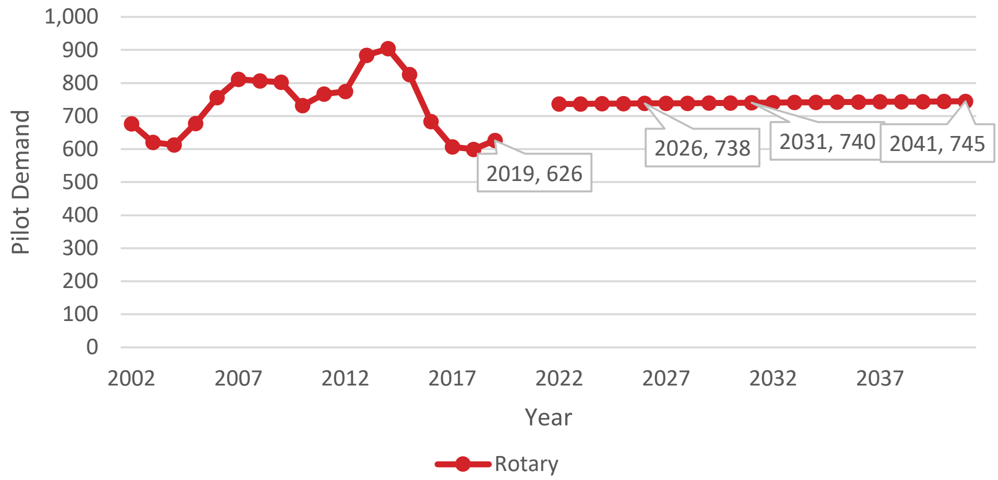
MEASURE	PILOTS PER AIRCRAFT	RATIONALE
Rotary	4.5	Assumes crews consist of (on average) 1.5 pilots (account for single + multi crew helicopters), and 3 crews are required to operate an aircraft in a given week

4.2.2 The process used to obtain an estimate for rotary pilot demand follows the same method described for Model 4:

$$Pilots\ demanded = \frac{ATMs}{Movements\ per\ aircraft * \ Pilots\ per\ aircraft}$$

[19] CAA's UK Airport data, Table 19

4.2.3 The historical trend shows that Rotary ATMs fluctuated considerably between 2002 and 2019. No clear increasing/decreasing trend in the data could be observed. Based on this data, an accurate prediction of future demand is difficult to justify. However, it can be said that through this period, it is estimated that rotary pilot demand ranged between 600 – 900 pilots per annum. The chart and table below shows the output from Model 8.



ROTARY PILOT DEMAND	2021	2026	2031	2041
Historical estimate	517	738	740	745

Figure 14. Historical and Forecasted Rotary pilot demand in the UK

Model 9 – Rotary Pilot Supply via Historical ATPL(H) + CPL(H) Licence Issuance

4.2.4 The historical supply of helicopter pilots was estimated from 2004 – 2018 using CAA records for the number of valid ATPL(H) and CPL(H) licences and new licences issued each year[16] [17]. Note: EASA/JAR and UK license figures were aggregated. Overall, the number of valid licences has not changed dramatically, however the composition of these licences has. There has been a steady decline in the number of valid ATPL(H) licences over the time period, and a corresponding increase in CPL(H) licences up to 2012. In more recent years, both licence types have started to decline at similar rates. Because of this, it is not clear what direction the trendline may move in the future and so a forecast based on this data was not undertaken.

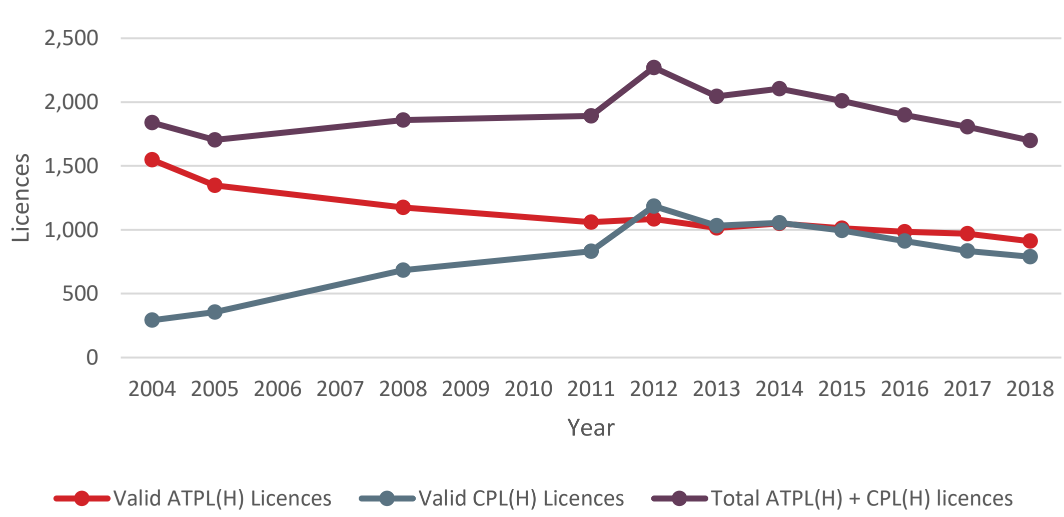


Figure 15. Historical supply levels of rotary pilots (2004 – 2018)

4.2.5 Historical trends for rotary pilot age demographics and licencing rates were analysed to understand whether a more informed view of future supply could be determined. These were constructed using CAA data[16] [17] and are shown below:

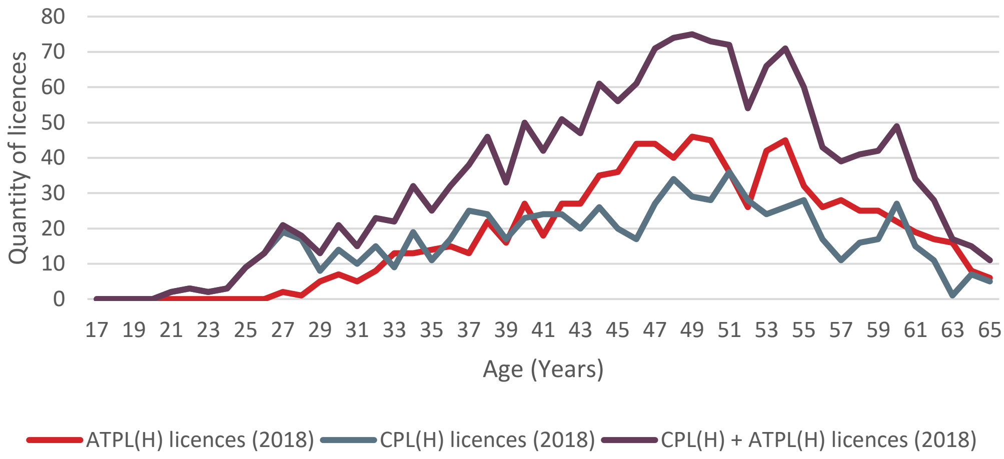


Figure 16. Valid commercial helicopter pilot licences by licence holder age, 2018

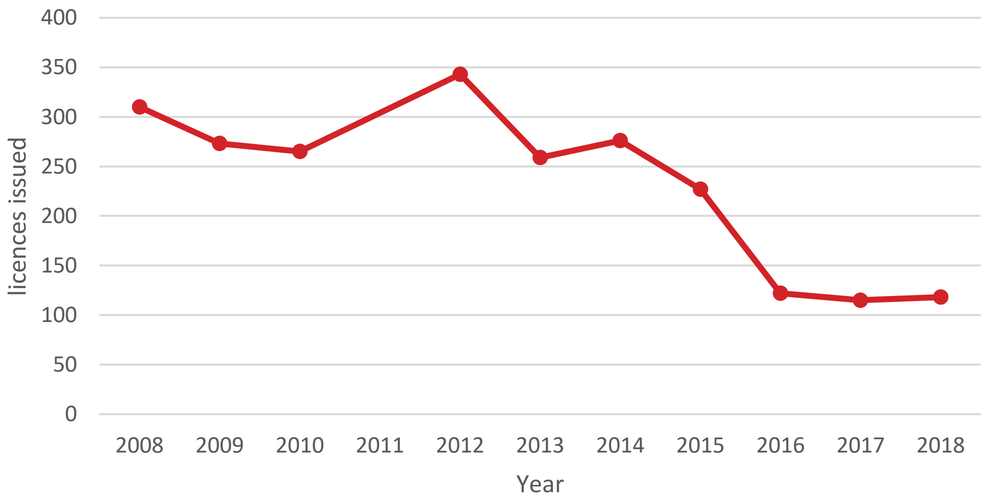


Figure 17. ATPL(H) + CPL(H) licences issued 2008 – 2018

4.3 Modelling Using DfT Jet Zero Strategy UK Air Traffic Forecasts

4.3.1 While the modelling approaches outlined in Appendix A use established industry reports (i.e. from Boeing and CAE[1]) as a key source for their projections, the study team also developed a methodology for using Air Transport Movement (ATM) outputs using data provided by the DfT from their latest UK air traffic forecasts prepared for the Jet Zero strategy. Although the associated passenger and carbon emission forecasts are in the public domain, this data, which is broken down by broad category of aircraft, is not. We have therefore set out the data provided by DfT in full, alongside the assumptions we have used to derive an overall high-level estimate of pilots, in Table 14.

4.3.2 The scenarios published for the Jet Zero Strategy uses the DfT's aviation model. The model framework was described in detail when a full set of forecasts was last published in 2017. The model has been updated in recent years in line with the DfT's policy of continuous improvement to its analytical models. Recent improvements have focused on bringing the model up to date to accurately represent UK aviation passenger demand, aircraft movements and emissions for 2019, the last normal year of aviation activity before the COVID-19 pandemic. Detail on the DfT aviation model updates and key modelling assumptions can be found in the Jet Zero: modelling framework document that was published as part of the Jet Zero: further technical consultation.

4.3.3 It is important to note that the capacity assumptions required by the Jet Zero modelling do not pre-judge the outcome of any future planning applications, including decisions taken by Ministers, and are not a prediction of what the DfT thinks will happen with future capacity expansion. However, specific assumptions about the future runway capacity must be made for the DfT aviation model to operate and these act as a reasonable upper bound of possible future airport capacity and resulting emissions and are consistent with current planning applications.

4.3.4 Finally, the DfT's forecasts are made by modelling long-term relationships between passenger aviation demand and its economic drivers. Input GDP and other income related forecasts include the projected wider impacts of the COVID-19 pandemic and recovery of the UK and world economies but this is the only direct inclusion of the pandemic effects in the main forecasts. It is therefore assumed that the long-term relationship between demand and key drivers estimated from historic data is unaffected by the pandemic. This is reasonable in terms of looking at long-term strategies for abating carbon (CO2e) emissions but it should be noted that the confidence in any forecast out to 2030 will inevitably be lower than in previous forecasting.

Table 13. Estimate of Pilot Requirements based on DfT Forecasts

AC TYPE	2019	2026	2031	2041	CONVERSION FACTOR: ATMS TO AIRCRAFT	PILOTS TO AIRCRAFT RATIO**
RegJet	185,364	236,514	357,536	331,184		
No. of Aircraft*	97	124	187	174		
No. of Pilots**	1,264	1,612	2,437	2,258	1,907	13
No. of UK Pilots***	884	1,129	1,706	1,580		
Narrow	1,366,107	1,383,698	1,423,476	1,675,812		
No. of Aircraft*	630	638	657	773	2,167	14
No. of Pilots**	8,825	8,939	9,196	10,826		
No. of UK Pilots***	6,178	6,257	6,437	7,578		
Wide	245,501	272,383	290,984	373,806		
No. of Aircraft*	393	436	466	599		
No. of Pilots**	7,080	7,855	8,392	10,780	624	18
No. of UK Pilots**	4,956	5,499	5,874	7,546		
TurboProp	260,941	197,029	74,346	62,949		
No. of Aircraft*	120	91	34	29	2,167	12
No. of Pilots**	1,445	1,091	412	349		
No. of UK Pilots***	1,011	764	288	244		
Total ATMS	**2,057,913**	**2,089,625**	**2,146,342**	**2,443,751**		
Projected Aircraft Serving UK	**1,241**	**1,290**	**1,345**	**1,575**		
Total No UK Pilots	**13,029**	**13,648**	**14,305**	**16,948**		

Source: DfT Jet Zero ATM Forecasts

*Conversion Factor: Typical number of sectors flown per day x 365 x 95% utilisation

**Number of aircraft x estimated average number of flight crew needed to fly single aircraft year round

***UK Pilots ratio of 0.7 applied - based on CAA 2019 data which indicates 36.5% of ATMs into/out of UK were flown by non-UK operators but taking into account those flying for non-UK airlines, on career breaks, flying part-time, retraining etc.

4.3.5 Table 14 takes the core data provided by DfT in bold and applies a similar approach as our earlier modelling – notably applying an aircraft/ATM ratio to calculate the number of aircraft needed to fly the DfT's forecast ATMs, and then estimating the number of pilots required based on that fleet size and typical pilot to aircraft ratios[20]. We have also then applied at UK pilot ratio to reflect the extent that the ATMs are flown by UK carriers or international carriers who employ significant UK flight deck crew.

4.3.6 Table 15 places the DfT Jet Zero ATM based forecasts alongside forecasts derived from the modelling approaches from industry sources set out in the majority of this Appendix.

Table 14. Comparison of Appendix A and DfT Based Forecasts - UK's Future Pilot Requirements

SOURCE OF FORECAST	2021*	2026	2031	2041
Appendix A - Min projected demand	13,464	20,572	23,462	27,810
Appendix A - Max projected demand	18,394	22,133	26,955	38,030
Project demand from DfT Forecasts	13,029	13,648	14,305	16,948
*Note: Not 2019				

4.3.7 The resultant output from modelling based on DfT data generates a more conservative set of pilot forecasts than the modelling based on industry sources. This is primarily a function of the fact that the DfT Jet Zero ATM input data projects a flatter (i.e. lower) rate of traffic growth for 10 years post pandemic than the industry forecasts imply; in addition the assumed fleet mix moving forward between the two sources of input data are somewhat different.

[20] The turboprop, narrowbody and wide body figures were cross-checked online and with representative UK airlines and found to be of the right order.