Future of Flight Scenarios

Futures Research Report

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Executive Summary

The Department for Transport (DfT) future of flight policy team and Government Office for Science (GO-Science) commissioned Frazer-Nash Consultancy to create a series of scenarios which can be used to model alternative future developments in the UK future flight market. These scenarios quantify the potential impact of future flight technologies on the UK macroeconomy, the environment, businesses and passengers. The outputs of this report are designed to help inform policy development and present the feasible bounds of impact of the future flight sector in the UK.

Technologies such as uncrewed air systems (UAS) and advanced air mobility (AAM) will play a key role in defining the future of flight. Given the relative infancy of these technologies and uncertainty surrounding user uptake and future developments there is a requirement for accelerated policy development to help guide the industry. This requires detailed understanding of the drivers and barriers that will affect AAM and UAS adoption in the UK. These include regulation, the wider UK and global economic situation, social acceptance and technological advancement.

This report concludes that future growth in these markets relies heavily on the public perceptions of the new technologies developed, the speed of technological readiness and the relative strength of market development in the UK compared to global UAS and AAM markets. Therefore, this report recommends that policy and regulation in future flight focuses on facilitating the growth of the manufacturing base, developing key manufacturing and operational skills, enabling early use of the technologies and stronger public relations.

Approach

The approach to developing future scenarios included six-stages, incorporating guidance from the HM Treasury Green Book, transport appraisal guidance (TAG) and the GO-Science Futures Toolkit.[1] The stages were:

1. **Horizon scan:** A review of existing evidence to analyse strategic, technological and economic trends in the UAS and AAM markets. The data gathered through the horizon scan was used to define a set of quantitative scenarios.
2. **Market driver and barrier mapping:** Identification of the political, economic, social, technological, legal and environmental (PESTLE) factors likely to contribute to changes in UAS and AAM adoption.
3. **Axes of uncertainty analysis:** The definition of diametrically opposed states for the key market drivers and barriers, providing a binary framework to build potential scenarios.
4. **SWOT analysis:** A strengths, weaknesses, opportunities and threats (SWOT) assessment providing the context required to down select the feasible types of scenarios.
5. **Scenarios development:** The building of the selected scenarios and their market characteristics to create evidenced input parameters for the economic model.
6. **Economic modelling:** Quantification of each scenario in terms of economic (market activity and contribution to the economy) and environmental impact using the data and trends identified in the horizon scan.

The analytical process incorporated the review of open-source documentation and outputs from stakeholder workshops. The stakeholder workshops included representatives from industry, academia and government, and informed stages two to four of the approach, known as the futures analysis. This provided additional evidence to validate the scenario development and economic model design.

[1] The Green Book (2022) - GOV.UK (www.gov.uk); Transport analysis guidance - GOV.UK; Futures toolkit for policymakers and analysts - GOV.UK (www.gov.uk)

Key Findings

Future of flight scenarios

This study developed four quantitative scenarios that each describe a potential future UK market for UAS and AAM from 2025 to 2050.

Scenario 1: Low sector growth: A lack of collective strategy and ambition between UK industry and government results in low growth in the domestic future flight sector. The global UAS and AAM market is highly competitive as other countries, and international regulators compete to attract future flight manufacturers. The UK has been left behind by the global markets. This scenario represents the worst-case scenario and the lower limit of the potential UK market size.

Scenario 2: Acceptance by business, but not by the general public: The public has a negative view of the sector due to technology demonstration setbacks and privacy concerns. However certain businesses experience benefits from efficient UAS services, providing cost reductions to operations. This results in regulation becoming tailored towards industrial UAS operations such as infrastructure inspections.

Scenario 3: Technology breakthrough in the AAM market in the UK: A technological breakthrough in the UK in batteries shortly after entry into service, increases the availability of AAM travel and reduces costs of travel for passengers. However, the adoption of beyond visual line of sight (BVLOS) and autonomous UAS is hindered with delayed regulation and entry into service due to the general public's privacy concerns.

Scenario 4: High sector growth: A collective strategy and ambition between industry and government results in high growth in the domestic future flight sector. There are no major blockers by regulators or the general public. This scenario represents the best-case scenario and the upper limit of the potential UK market size.

These scenarios capture a range of market drivers and barriers, which were devised during a workshop with government, industry and academia stakeholders. The drivers and barriers were transformed into market elements which have been used to define an economic model quantifying the impact of future flight in the UK. The headline market elements are market activity, trade and the environment. Figure 1 shows the magnitude for each market element across the scenarios.

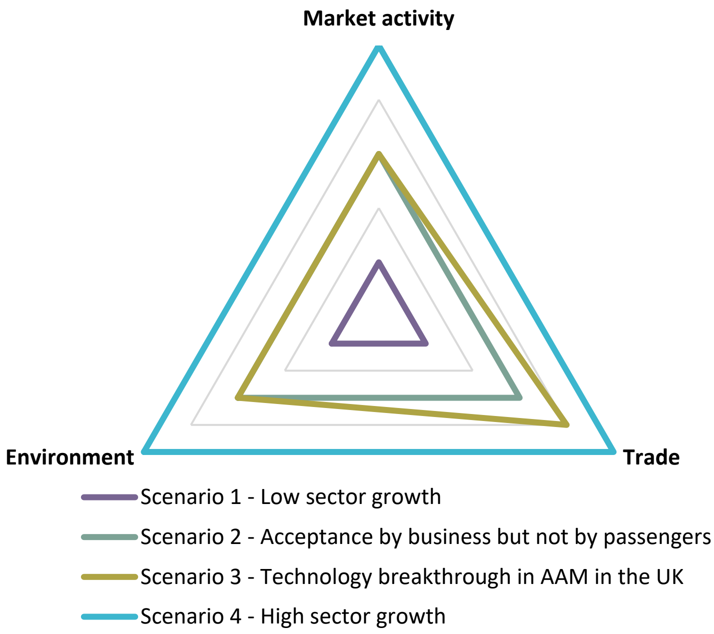

Figure 1: Magnitude of the market elements for each scenario.

Potential market size

The results show that the combined UAS and AAM markets could generate up to £5.7 billion in annual revenue in 2050 (high sector growth scenario), equivalent to approximately 19% of the £30 billion in annual revenue generated by the UK aerospace sector in 2023.[2]

The estimated annual revenues of the UK UAS and AAM markets from 2025 to 2050, are shown in Figure 2 and Figure 3, all figures in the executive summary relate to the impact under current economic growth trends. Cumulative UAS revenue is estimated to be between £20.3 billion and £66.2 billion across this time period. The results show that there will be high UAS sector revenue growth under scenarios 2 and 4, and low revenue growth under scenarios 1 and 3. The AAM market has substantially more variation between scenarios than the UAS market. In the AAM market the cumulative revenue is as high as £5.7 billion in scenario 4, while for scenarios 1 and 2, it is just £300 million and £764 million respectively.

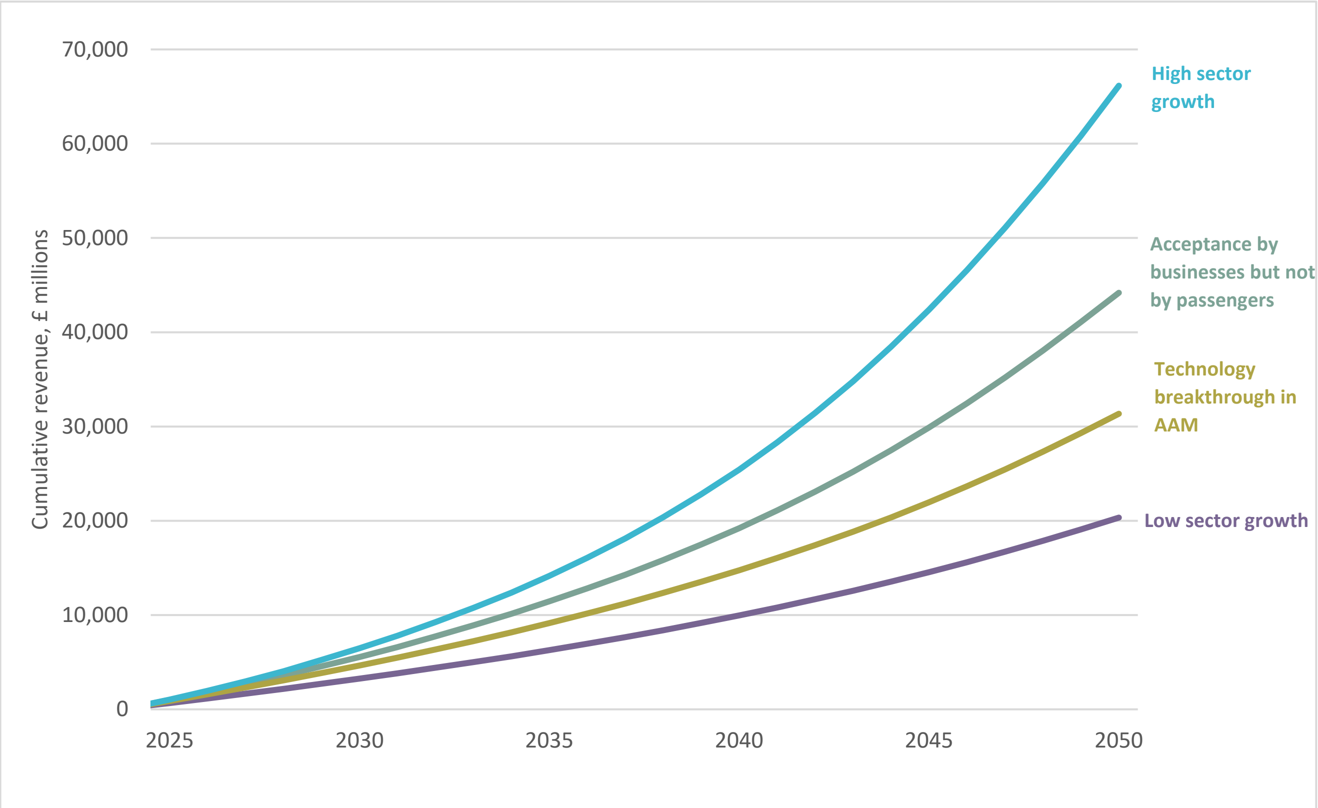

Figure 2: The progression of cumulative revenue for the UAS market under each scenario. Cumulative UAS revenue ranges from £20.3 billion to £66.2 billion

Reflecting on the key differences in the assumed speed of technological readiness and the relative strength of market development in the UK compared to global markets, the results from scenarios *1: Low sector growth* and *4: High sector growth* represent the upper and lower bounds of the estimated potential market size by 2050.

The differences in potential market growth estimated for scenarios 2 and 3 reflect the nuances of varying levels of public support for the new technologies. These scenarios highlight the importance of public perceptions in developing both the markets and therefore indicates that policies and regulation should target facilitating positive public perceptions as a key priority.

[2] UK aerospace sector remains healthy in the first half of 2024, says ADS Group - ADS Group

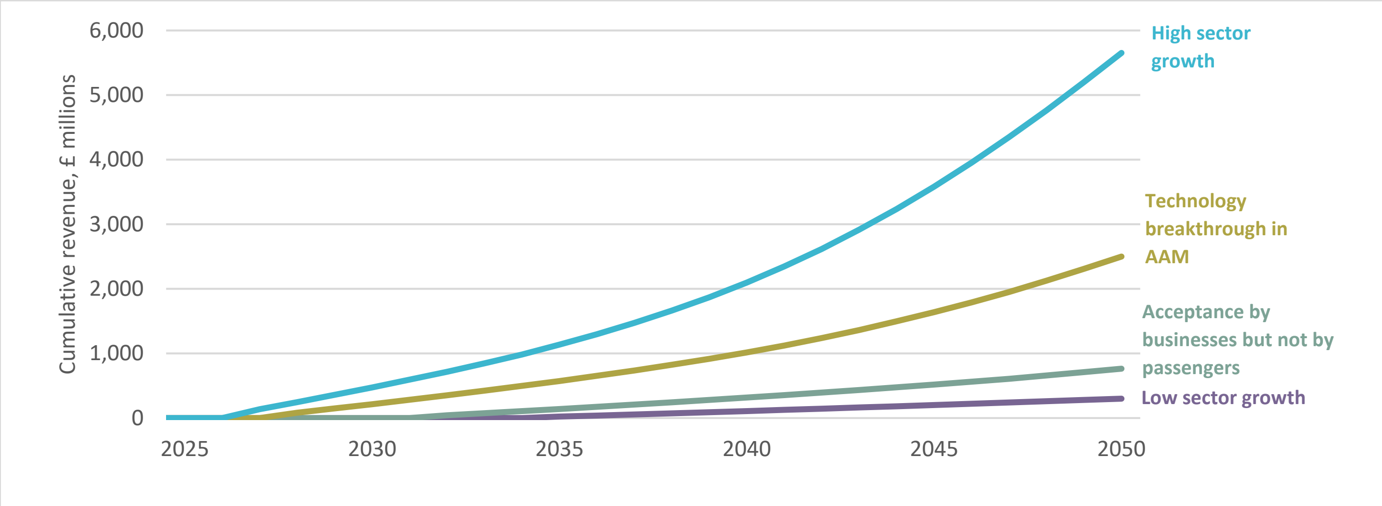

Figure 3: The progression of cumulative revenue for the AAM market under each scenario. This includes revenue from ticket sales, vehicle sales, and vertiport expenditure. Cumulative AAM revenues range from £300 million to £5.7 billion

Social and economic impact by 2050

UAS and AAM are estimated to contibute £103 billion to the UK economy by 2050 in the high sector growth scenario. This includes the direct impact of AAM and UAS through manufacturing and commercial revenues, as well as the indirect and induced impact across the supply chain.

Figure 4 shows the estimations of the accumulated direct, indirect and induced gross value added (GVA) of UAS and AAM markets by 2050 under each scenario. The cumulative GVA generated by UAS and AAM adoption ranges from £24 billion in scenario 1 to £103.3 billion in scenario 4, or £1.5 billion to £8.3 billion annually by 2050. This estimated impact represents the gross contribution to the UK economy.

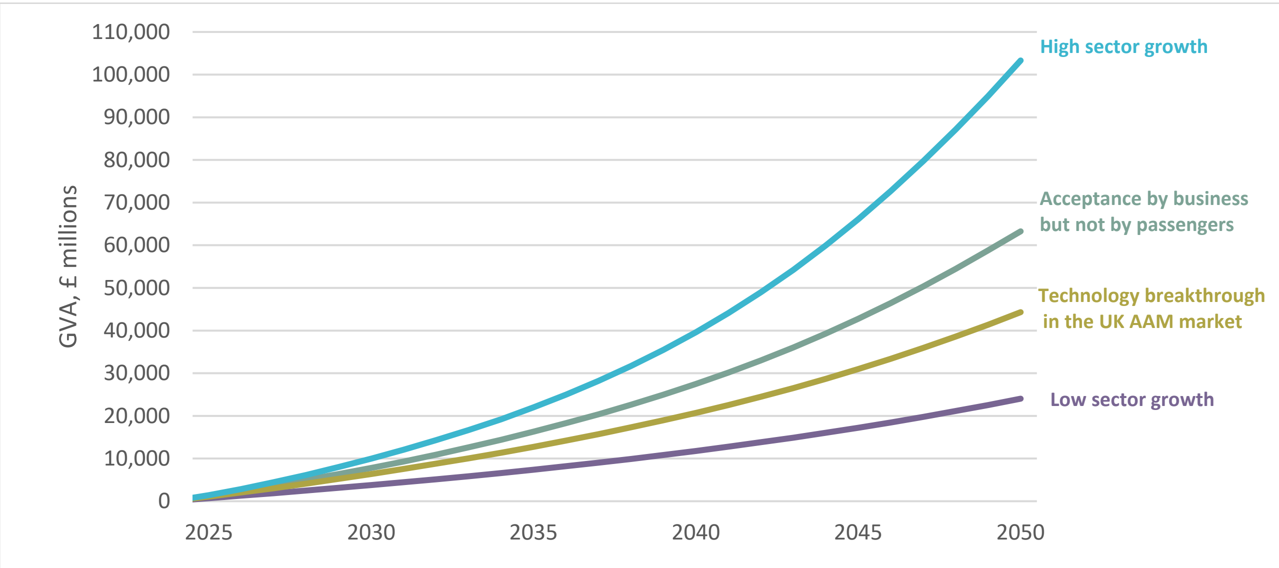

Figure 4: Accumulated gross value added for all scenarios by 2050.

Compared to traditional vehicle types, UAS and AAM use leads to a reduction in greenhouse gas emissions. The social benefits produced by this reduction is estimated to range from £10.2 million in scenario 1 to almost £124.3 million in scenario 4.

The results of this study provide insight into the drivers and barriers that cause the variation in the potential growth of the UAS and AAM markets. Using the developed scenarios, this report shows that future growth in these markets relies heavily on the public perceptions of the new technologies developed, the speed of technological readiness and the relative strength of UK market compared to global UAS and AAM markets. Therefore, this report recommends that policy and regulation in this area focuses on:

- enabling early use of the technologies, and
- public relations to support end user use,
- development of associated manufacturing and UAS operational skills,
- facilitating the growth of the required manufacturing base.

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1 Introduction

The Department for Transport (DfT) future of flight policy team and Government Office for Science (GO-Science) futures team have commissioned Frazer-Nash Consultancy (Frazer-Nash) to create a series of scenarios which can be used to model future developments in the UK future flight market.

The UK government has set out how it intends to embrace innovation for a sustainable future, including new aircraft vehicles such as drones and electrical vertical take-off and landing aircraft (eVTOLs).[3] A Future of Flight Action Plan was developed with a vision that includes enabling the introduction and scaled adoption of the new aircraft. A clearly defined view of how the uncrewed air systems (UAS) and advanced air mobility (AAM) sectors might develop in the future is needed to ensure future of flight policy, regulation and public and private investment activities are well informed. This will help to ensure policy decisions are better suited to a range of plausible future scenarios in an emerging and uncertain policy area.

The aim of this project is to produce a set of future of flight scenarios, covering potential future states of the UK electric UAS and AAM sectors, and quantifying the economic and environmental impact these technologies will have. The project makes explicit assumptions about key drivers and barriers in these scenarios and explores the UK's strengths, weaknesses, opportunities and threats to identify gaps and competitive advantages to the global markets.

The purpose of this report is to summarise the futures analysis process and explain how this has been used to build these scenarios for economic modelling as well as adding to the existing future of flight evidence base. This report combines the existing evidence surrounding UAS and AAM sectors with stakeholder insight. These scenarios are first described qualitatively and then mapped on to a range of quantitative market characteristic to allow the impact on the UK economy and environment to be estimated.

This study focuses on the potential UK market, meaning that the global impact is not explicitly estimated. However, the global market context was used as a key driver to produce explanations of how UK-based AAM and UAS firms may react within different future global contexts. The forecast period in this study runs from 2024 until 2050 to align with DfT aviation forecasts and UK Government net zero targets.

1.1 Electric uncrewed air systems (UAS) and electric advanced air mobility (AAM) sectors

We are accelerating towards significant potential changes in the aviation sector where technologies such as UAS and AAM could play a key role in delivering operational efficiency, national security and industrial resilience across the globe. This study focuses on the future of UAS and AAM sectors, defined as follows:

Advanced air mobility (AAM) is the next generation of air transport systems intended for urban air mobility (UAM) and regional air mobility (RAM) solutions. This study considers small, electrically powered piloted and autonomous AAM aircraft (up to 20 passengers).

Uncrewed air systems (UAS) are aircraft, and their associated elements, which are operated with no pilot on board.[4] For this work, UAS platforms will include electrically powered, remotely piloted and autonomous drones.

Sustainable aviation fuels (SAF) and hydrogen technologies were not in scope for this study.[5] In addition, the UAS estimates are solely for commercial UAS applications and not the leisure market. This is because the leisure market is close to maturity and will likely not experience the same levels of growth as the commercial market. In addition, there is a higher degree of uncertainty surrounding commercial use cases and future commercial UAS platforms and operations. Therefore, a scenario based approach must focus on the commercial market due to higher levels of uncertainty than the leisure drone market.

[3] Department for Transport. (2022). Flightpath to the Future.
[4] British Standards Institute. (2023). BSI Future Flight Systems – Vocabulary August 2023 Version 1
[5] Department for Transport. (2022). Jet Zero Modelling Framework.

Evidence from the horizon scanning activities was used to bound a series of use cases to inform the likely applications of AAM and UAS vehicles in this study. This approach, advocated for by the civil aviation authority (CAA)[6] accounted for the different applications of AAM and UAS and allowed for variation in vehicle type within each scenario, capturing uncertainties surrounding future operations. This study focuses on the following use cases:

- **Regional air mobility (RAM): AAM** – Moving passengers between cities and regions (journeys over 100km).[7]
- **Urban air mobility (UAM): AAM** – Transit within cities (journeys between 5km and 100km).[8]
- **Last mile delivery: UAS** – Delivery of parcels to their destination.
- **Commercial site operations: UAS** – Infrastructure inspection over large distances or structures.
- **Emergency services immediate response: UAS** – Support to emergency services.

1.2 Contribution to the existing evidence on the future of UAS and AAM sectors

There is significant variation in the existing evidence on the future size of the UAS market. Whilst high levels of uncertainty are a natural feature for forecasting over a medium- and long-term horizon, the uncertainties surrounding public perception, regulation and incentives for business investment are particularly acute in the fledgling UAS and nascent AAM markets. Previous work states that the growth in the UK UAS market is estimated to contribute up to £45 billion to the UK economy by 2030,[9] and the socioeconomic impact of the UK AAM market could be between £1 and £2 billion annually by 2040.[10] In addition, further estimates suggest £704 million could be earned by AAM operators through fares in the UK.[11] Beyond UK markets, Brycetech indicates that AAM could see between £1 billion and £100 billion in service revenue globally in 2040.[12]

Building on existing research, this project contributes to the UAS and AAM sectors evidence base by explicitly considering AAM and UAS use cases within the same analysis and providing a range of estimates for the potential future market size driven by a series of plausible scenarios. This work considers the economic and environmental impacts of AAM and UAS in the UK, whilst also considering how changes in public acceptance, regulatory readiness and technical improvements influences the potential market activity for these technologies.

1.3 Report structure

The remainder of this report is structured as follows:

- **Section 2:** Describes the methodological approach.
- **Section 3:** Details the scenario development leading to the creation of four qualitative scenarios and a market characteristics framework.
- **Section 4:** Using the market characteristics, this section describes the development of economic modelling to define a set of quantitative scenarios.
- **Section 5:** Presents the estimates for UAS and AAM market size and impact on the UK economy and environment by scenario.
- **Section 6:** Conclusions and recommendations.

[6] Civil Aviation Authority. (2021). Advanced Air Mobility: Taking a use case approach to develop regulation.
[7] BryceTech. (2023). Advanced Air Mobility.
[8] BryceTech. (2023). Advanced Air Mobility.
[9] PWC. (2024). Skies without limits v2.0.
[10] PWC. (2023). Advanced Air Mobility – UK Economic Impact.
[11] IUK-02112022-Advanced-Air-Mobility-Demand-Assessment-Report.pdf (ukri.org)
[12] BryceTech. (2023). Advanced Air Mobility.

2 Methodology

This study created a series of plausible scenarios of the future of flight ecosystem and evaluated their economic impact on the UK. It followed a six-step analytical process based on the GO-Science futures toolkit and transport appraisal guidance (TAG), as summarised in Figure 5.

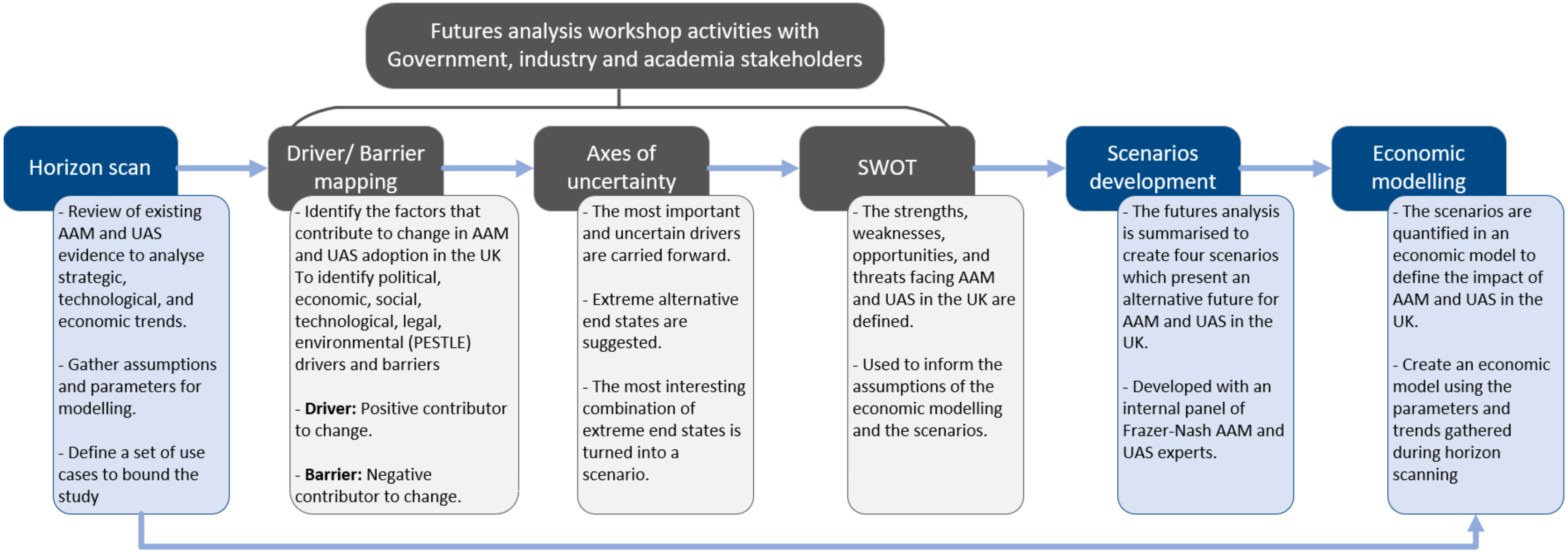


Figure 5: The approach integrates the GO-Science Futures Toolkit in a six-step process.

The approach followed the scenario creation framework laid out in the GO-Science Futures Toolkit pathway seven; a best practice approach to identify future opportunities and threats and prioritise the actions that must be taken to develop a policy area. [13] Pathway seven was well suited to the future flight market due to the high levels of uncertainty and the wide variety of potential use cases. The pathway also aligned with the goals of this study as it is often used to inform policymakers who can take actions to minimise threats and maximise opportunities.

The following sections describe the methodology used for scenario development and economic modelling.

2.1 Qualitative scenario development

The scenarios and use cases were discussed at a high-level and in detail to capture industry context, trends and likely developments by 2050. The development of the qualitative scenarios followed the GO-Science Futures Toolkit process:

1. Identification of the market drivers and barriers (MDABs).
2. Definitions of the critical uncertainties for a policy area or market (Axes of uncertainty).
3. Strengths, weaknesses, opportunities and threats (SWOT) analysis.

Each stage of this process was created with key stakeholders and considered the perspectives of government, academia and industry. The result was a narrative description of each scenario, describing the market state in 2050.

2.1.1 Mapping market drivers and barriers

A PESTLE (political, economic, social, technological, legal and environmental) analysis identified the factors that are likely to be the most influential in driving or preventing change in future AAM and UAS markets. This exercise explored the perspectives of government, academia and industry to capture a wide range of factors. Throughout the process, the following definitions were adopted for drivers and barriers:

- **Driver:** A factor that can accelerate the adoption of AAM and UAS in the UK.
- **Barrier:** A factor that can hinder the adoption of AAM and UAS in the UK.

Stakeholder responses were collated, combined and refined to generate a distinct set of market drivers and barriers (MDABs). Annex A reports all the identified MDABs that were mapped by stakeholders on an importance-uncertainty matrix, allowing the most relevant MDABs to be identified. The most relevant MDABs were classified as both highly important and highly uncertain; these MDABs were explored further through the axes of uncertainty.

2.1.2 Axes of uncertainty

Axes of uncertainty is a tool that uses the MDABs to define the critical uncertainties for a policy area or market. In this study, the tool was used to identify the key uncertainties behind the MDABs and define the realistic end states of those uncertainties. Each uncertainty was presented on an axis between two completely opposed states.

For example, a key market driver identified in this study was the level of public acceptance to UAS/AAM. Two opposed states were identified to bound the uncertainty behind this market driver:

- **The extreme negative end state in 2050:** Active public opposition to UAS/AAM.
- **The extreme positive end state in 2050:** Everyone understands the benefits and accepts the UAS/AAM systems.

An initial filter was applied to identify the combinations of MDABs (potential scenarios) that were:

- **Logical** (no contradictions), and
- **Interesting and relevant** (as identified in the horizon scanning activity and workshop).

The most interesting, logical and relevant MDAB combinations were taken forward.

[13] Futures toolkit for policymakers and analysts - GOV.UK

2.1.3 SWOT analysis

The strengths, weaknesses, opportunities and threats (SWOT) analysis introduced the context from industry, to undertake further refinement of the draft scenarios. The analysis drew on the expertise of workshop participants to understand the future AAM and UAS ecosystem in detail. This provided the evidence to fully develop the surrounding narrative for the scenarios.

The SWOT analysis focused on industry, supply chain, regulation and government policy. The outputs were used to assess the extent to which potential scenarios reflected a plausible set of future outcomes. The SWOT analysis served as a final filter to down select scenarios, enabling four high-level scenarios to be defined.

2.2 Quantitative scenarios development

This stage of the scenario development process defined the quantitative parameters that describe the size, shape and success of future UK AAM or UAS markets. The qualitative scenarios used the MDABs to develop a set of market characteristics which describe the shape and size of market activity, including parameters such as demand growth, prices, and imports. These formed the framework for the quantitative scenarios by the below process:

- Horizon scan of existing forecasts, timelines and developments.
- Identification of how the MDABs mapped to each scenario.
- Quantification of market characteristics based on current or forecasted figures for the future AAM and UAS markets. The values assigned to each market characteristic were informed by horizon scan and the qualitative scenarios.

The result was a set of quantitative market characteristic values that described the qualitative narrative for each scenario. The values were developed during the horizon scan and refined throughout scenario development. These values served as inputs into the economic model.

2.2.1 Horizon scanning

To develop a set of comprehensive future flight scenarios, it was important to understand existing forecasts, timelines and developments for AAM and UAS. A future flight sector horizon scanning activity was undertaken, a range of open-source documentation was reviewed to capture key parameters, assumptions, uncertainties and use cases within the sector. Each data type is described below:

- **Parameter:** A numeric or measurable value that can define a system (e.g. number of UAS by 2050). These parameters were used to quantify the scenarios.
- **Assumption:** A statement which is accepted as true to help define a system. These assumptions supported the mathematical interactions within the model.
- **Uncertainty:** A statement that implies more than one outcome is possible (e.g. future GDP growth). The key uncertainties were investigated through the futures workshop to identify how these could vary across scenarios.
- **Use case:** An application of a technology that meets the needs of an end user. The use cases were used to bound the scope of the study.

The horizon scan focused on data extraction beyond present-day activities. Specifically, the analysis explored medium- and long-term futures. This helped bound the study and provided alignment with horizons two and three from the GO-Science futures toolkit.[14]

Horizon two focused on evaluating existing market trends and strategies to help inform and adapt future policy in anticipation of the sector's future needs. Horizon three aimed to understand the drivers for change and how these could affect future opportunities and threats. For the purposes of this activity, the medium-term was defined as 2035+, whilst the long-term was defined as 2050+.

[14] Futures toolkit for policymakers and analysts - GOV.UK

The parameters gathered during the horizon scan were used to quantify the market characteristics, explained in upcoming section. These were varied across scenarios to translate the qualitative work into the quantitative model.

2.2.2 Market characteristics

To construct a realistic set of quantitative scenarios, evidence from the horizon scan was used to develop a framework of market characteristics and associated likely values. The framework described the factors that influence a future market size, shape and success by considering:

- Technological advancements and development in services offered,
- Costs of new technology,
- Demand growth and uptake of the new services,
- Consumer sentiment towards the new technologies,
- Strength of global UAS and AAM markets, and
- Strength of the wider UK economy.

The detailed framework, discussed further in section 4, was populated with likely values for the initial (current) state of the market and values for the changes over time until 2050. These values were derived from mapping scenario MDABs (e.g. attitudes towards AAM) to market characteristics (e.g. demand for AAM products) as follows:

1. Identification of the MDABs with the most influence on market characteristics. These MDABs were considered in more detail, drawing on evidence from the SWOT analysis and stakeholder workshop.
2. Construction of the future UK context, global context, UK AAM market and UK UAS market for each scenario from the most relevant MDABs. This provided the evidence required to define and assess market characteristics for each scenario. This process also enabled further development of each use case, allowing the relative market growth rates of these use cases to be specified.
3. Assessment of market characteristics for each scenario, on a scale from very low to very high.
4. Quantification of the market characteristics based on current or forecasted figures for the future AAM and UAS markets. The qualitative assessment impacted the quantitative value assigned to each market characteristic; for example, if a characteristic was assigned a score of one (very low), then its value would be significantly below the central forecast.

In each case, values used are considered the most likely to occur in each scenario and are evidenced by existing research and/ or derived from the judgement of external stakeholders. The full set of values is presented in section 3.4.

2.3 Economic modelling

A bespoke economic model was developed to quantify the impact of each future flight scenario on the UK economy. The assumptions were defined by the market characteristic values and the workshop outputs, as set out in the previous section. The model was composed of multiple sub-models, each sub-model contained a set of market characteristics (as well as other inputs) for AAM and UAS. The function of each sub-model is as follows:

- **UAS users model:** To forecast UAS users and their demand until 2050. The model analysed CAA drone and model aircraft registration and education scheme (DMARES) statistics for drone registrations by using an elasticity-based economic model to calculate drone demand for each year to 2050. Demand growth depended on the scenario specific assumptions relating to end user buy-in, and the diversity of use cases.

- **UAS market revenues model**: To forecast UAS market revenue until 2050. This model used UAS platform and infrastructure prices to estimate the revenue generated from UAS technology sales. This model also uses UAS contractor prices to estimate the commercial revenue generated from the provision of UAS services.

- **AAM demand model:** To estimate annual AAM demand for passenger journeys until 2050. Demand for AAM was modelled through an industry lifecycle (S-curve) approach. Demand depended on how the ability of AAM to capture part of the taxi market was influenced by social acceptance of AAM and physical infrastructure readiness.

- **AAM supply model:** To forecast the number of AAM vehicles and infrastructure required to meet the demand of AAM services. AAM supply depends on the regulatory readiness for AAM vehicles, as well as the supply of skills which will affect changes in AAM production costs over time.
- **Economic impact model:** To estimate the direct, indirect and induced economic impact of the UAS and AAM markets. This model used Office for National Statistics multiplier analysis to calculate impacts on gross value added (GVA) and employment generated as a result of UAS and AAM market activities.
- **Environmental impact model:** To calculate the impact of UAS and AAM adoption on greenhouse gas emissions. The model used forecasted vehicle efficiency and usage rates alongside Department for Transport Analysis Guidance (TAG) factors to monetise the environmental impact of UAS and AAM take-up.

Section 4 provides the detailed methodology used for each sub-model.

3 Scenario development

This study developed four scenarios for the UK future flight market. This section provides the results of the scenario development exercise to construct qualitative descriptions for each scenario and a set of market characteristics that are used to define the economic model in Section 4. The scenario development process was:

- Define the scope of the future flight use cases.
- Summarise the qualitative scenario developed from stakeholder engagement.
- Follow the market characteristics framework used to develop the economic model.
- Determine the applicable modelling assumptions, developed from the scenario-specific identified market drivers and barriers.

3.1 Future flight use cases

The horizon scan identified a longlist of eighty use cases which were combined and internally down selected to five broad case studies to reflect those with the largest potential impact. The use cases served three purposes:

1. To identify specific applications for AAM and UAS in a future market, and to illustrate how these use cases could be affected by the four scenarios.
2. To provide a sense-check for the economic modelling calculations; if use cases are expected to be plentiful and high-value, then modelling results should reflect this.
3. To bound the scope of the scenarios as many of the impacts will be use case specific.

The five case studies that were identified are:

- **Regional air mobility (RAM): AAM** – Moving passengers between different cities and regions in the 100-1000 km range. This includes electric vertical, short, and conventional take-off and landing (eVTOL/ eSTOL/ eCTOL). These aircraft would use existing airport/airfield infrastructure; however, these sites would require significant investment to enable the charging of electric aircraft.

- **Urban air mobility (UAM): AAM** – Transit within cities, using eVTOLs, on journeys of less than 100km. The development of purpose-built urban vertiports will be necessary to enable these operations. The first examples in service of this use case are expected by 2026.[15] The two AAM use cases cover the entirety of the potential AAM market as defined by the British Standards Institute.

- **Last mile delivery: UAS** – Delivery of parcels to their destination. This could range from small UAS vehicles delivering parcels directly to houses and shops inside cities, with delivery times as short as three minutes, to large UAS vehicles delivering large 20kg parcels over a significant distance, such as medical supplies to hospitals.

- **Commercial site operations: UAS** – UAS performing infrastructure inspection over large distances or structures where beyond visual line of sight (BVLOS) or autonomous operations are required. This has many potential applications such as surveying a water network to prevent leaks, or monitoring emissions in the oil and gas industry.

- **Emergency services immediate response: UAS** – UAS operations to support emergency services. This consists of long-range, high endurance systems being used to survey a large area to locate lost and potentially injured individuals.

[15] Future of Flight Industry group. (2024). UK Future of Flight Action Plan

3.2 Market drivers and barriers

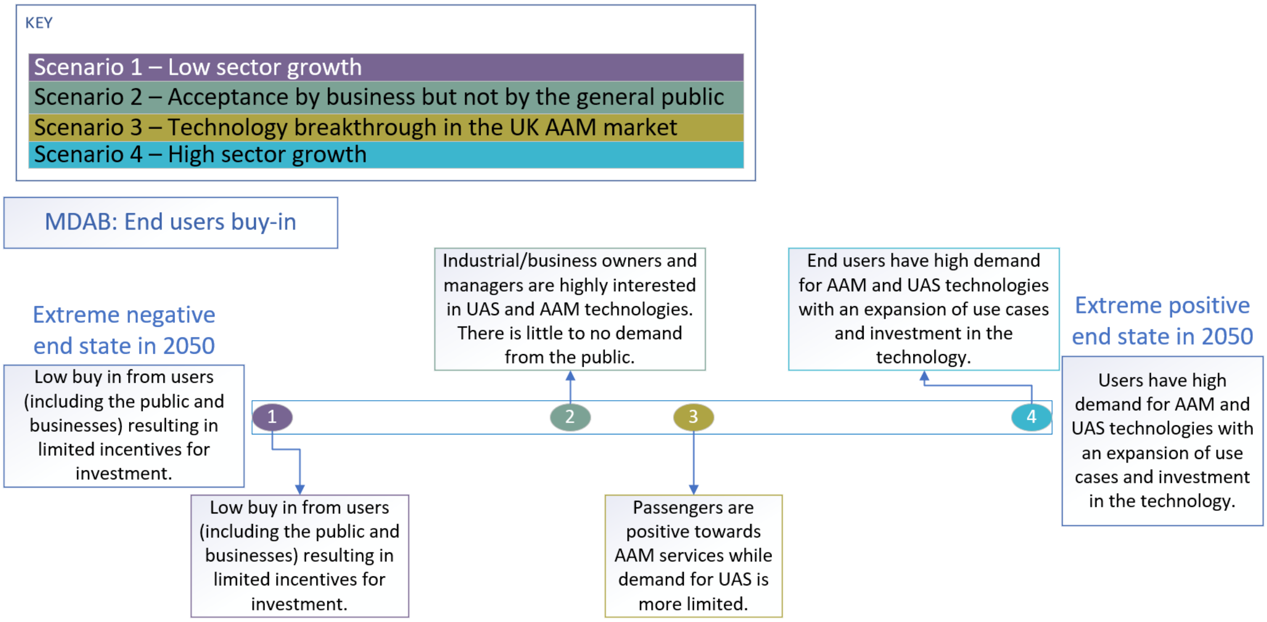
A workshop with government, industry and academia identified thirteen MDABs (Table 1) that are likely to have the largest influence on how the future flight market evolves. Collectively, they define the ways in which scenarios may vary and they integrate industry context to explain the plausible variations within the future flight market.

Table 1: Market drivers and barriers categories

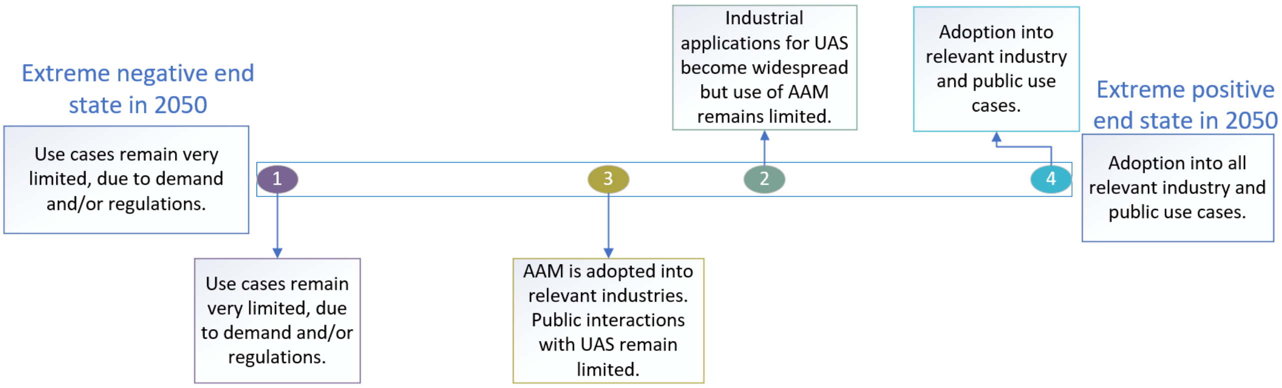
Internal factors - Actions related to the activity of end users, general public, and regulators in the UK.				External economy - global and nationwide factors
End user buy-in	Future airspace management	Diversity of use cases	Regulatory timeliness	State of the UK economy
Local planning laws	Public/social acceptance	Proactive regulation	EV charging readiness	Global stability
Long term research and development	Political will	Future skills		

The workshop also featured an axes of uncertainty exercise which involved assessing the extreme end states of each MDAB. These end states were used to bound the scenarios. For each scenario, an MDAB was either in the positive or negative state. The external economy assumptions were not varied across scenarios due to being external to the UK future flight sector, instead macroeconomic parameters have been used as sensitivity analysis for each scenario. Figure 6 provides the MDAB states for each scenario.

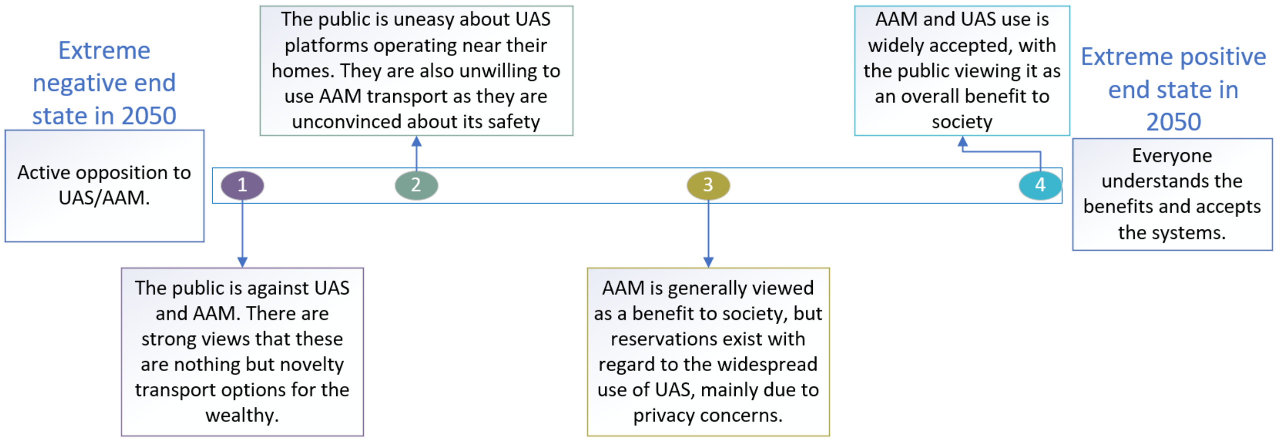
Figure 6: The state of each market driver and barrier for each scenario.



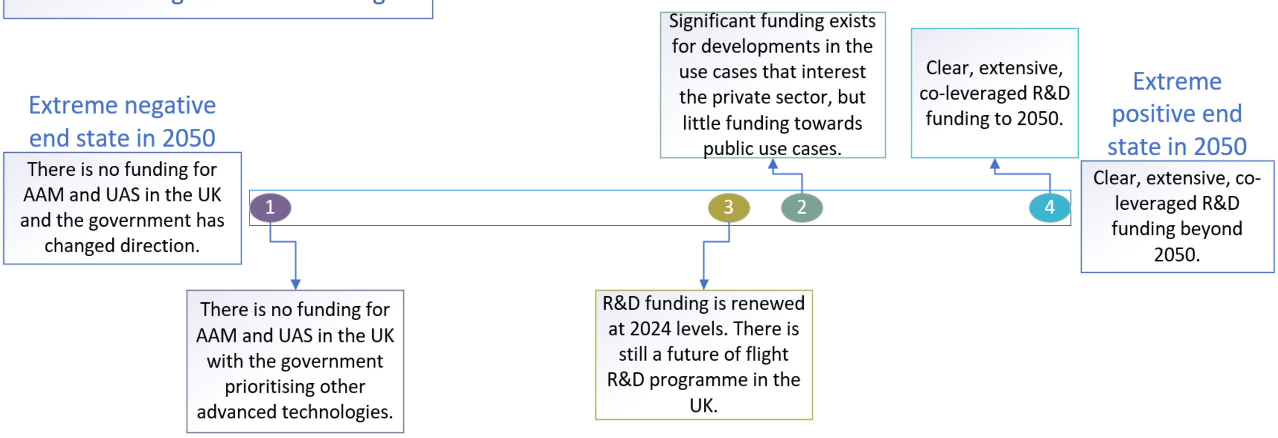
MDAB: Diversity of use cases



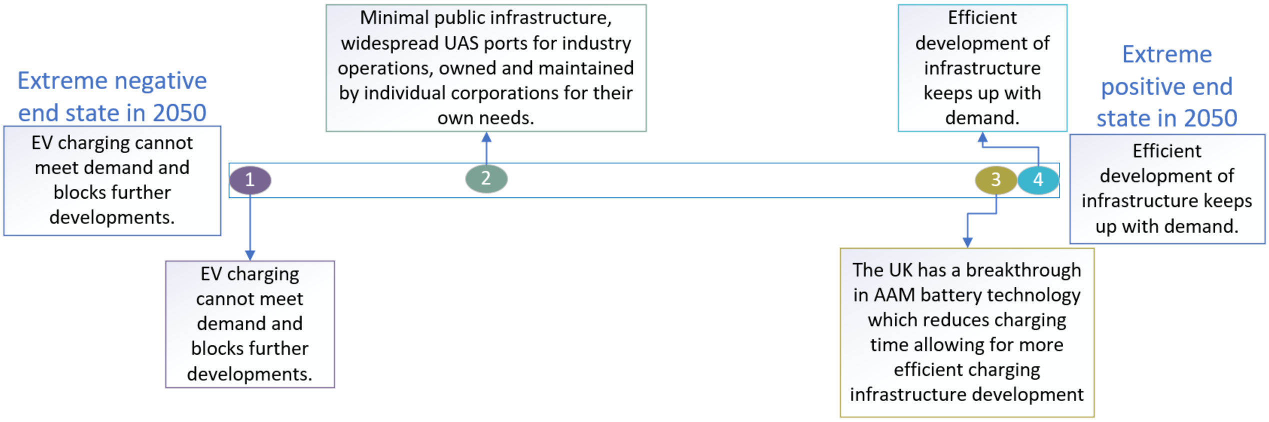
MDAB: Public and social acceptance



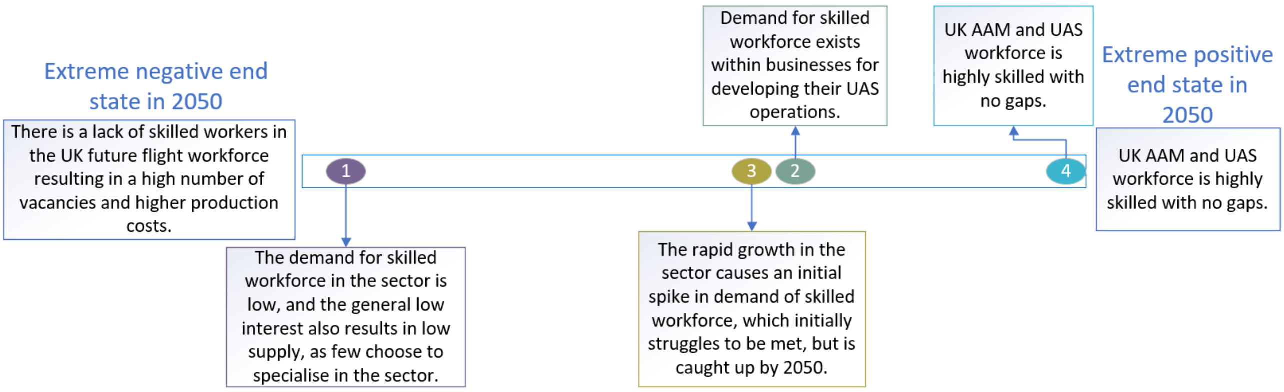
MDAB: Long term R&D funding



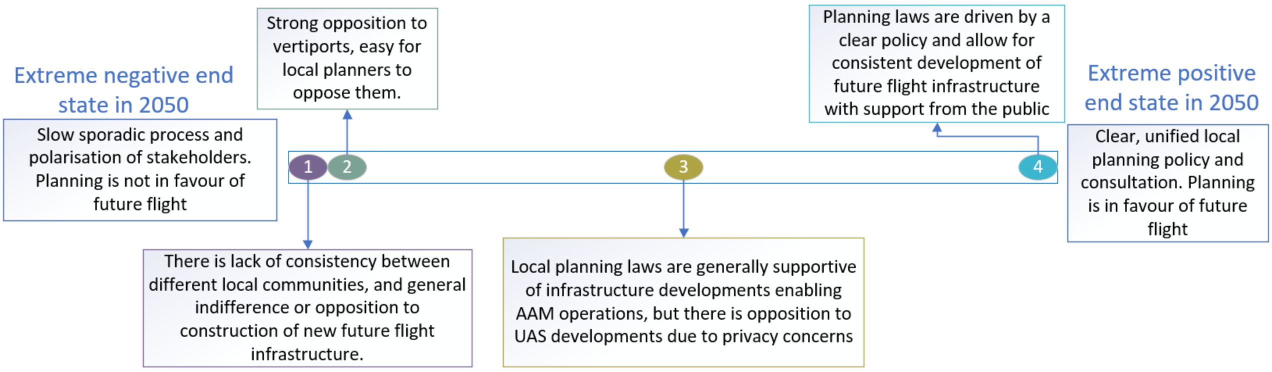
MDAB: EV charging readiness



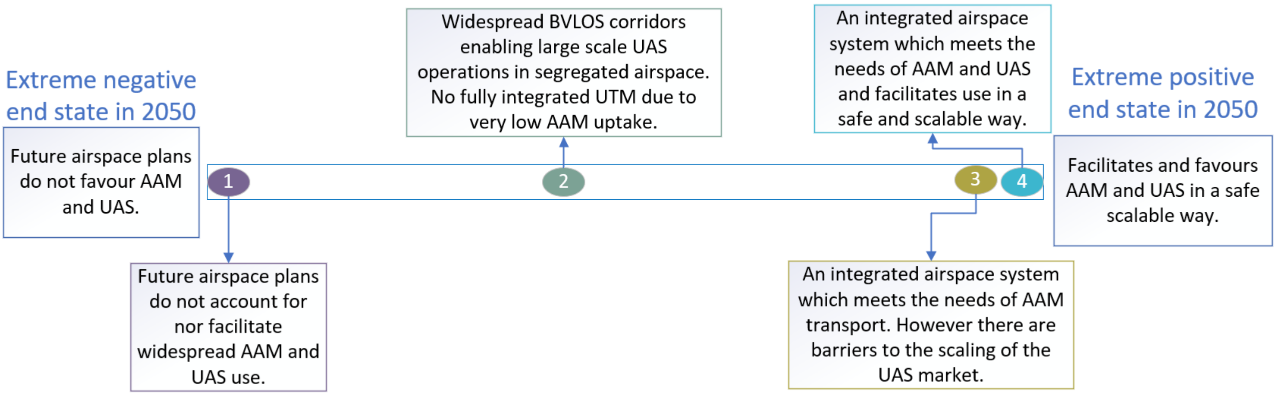
MDAB: Future skills supply and demand



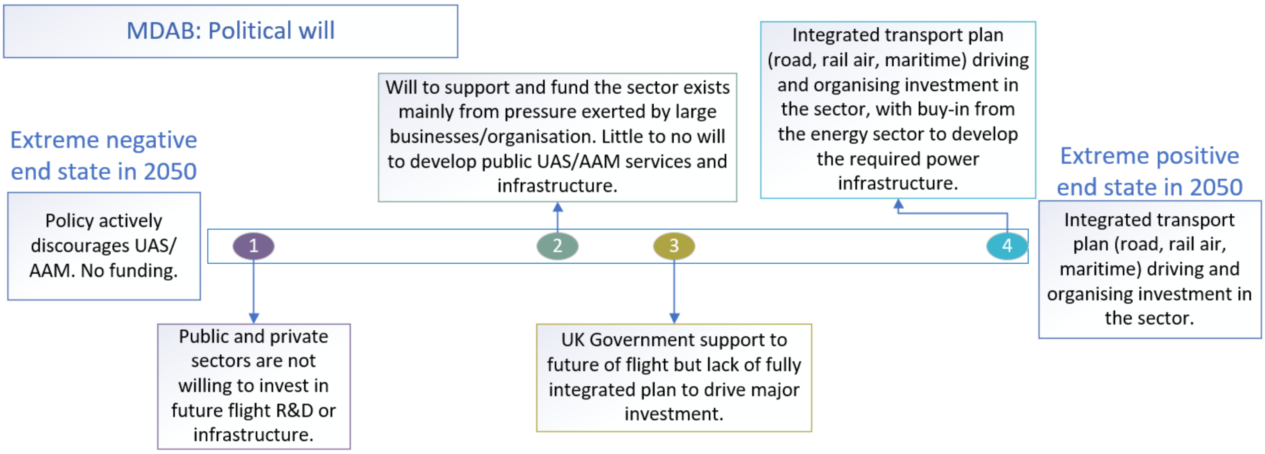
MDAB: Local planning laws



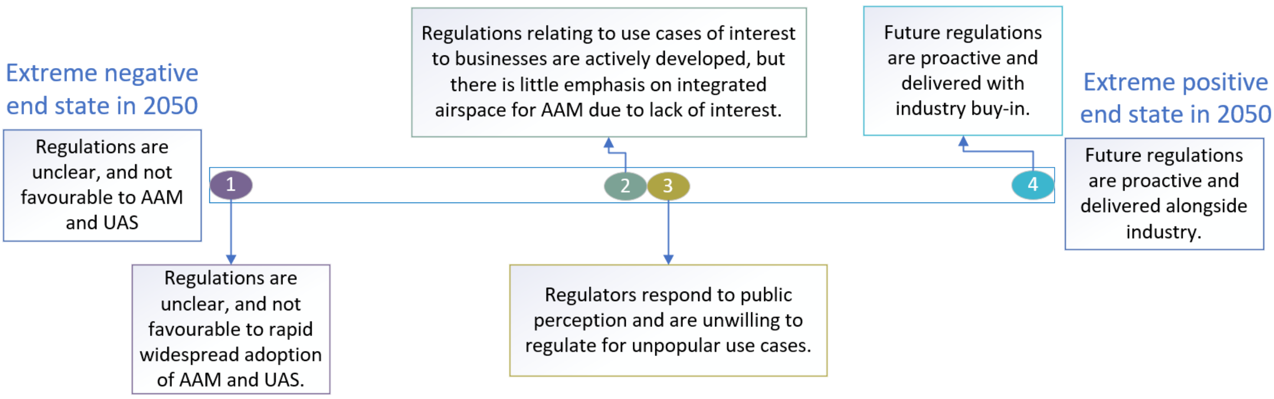
MDAB: Future airspace management

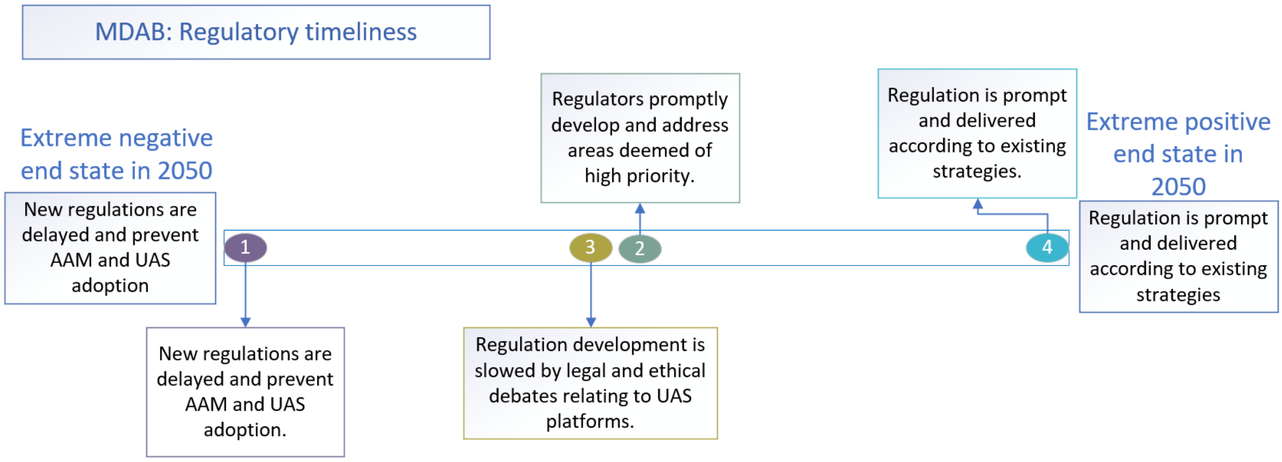


MDAB: Political will



MDAB: Proactive regulation





3.2.1 Scenarios per use case breakdown

The extent of the roll-out of each use case varies by scenario as producers of AAM and UAS technology make dynamic choices that reflect the opportunity presented in the scenario they are in. Table 2 presents the application of each use case and its success under each scenario.

Table 2: Scenario use cases

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Urban Air Mobility	Luxury private hire services.	Luxury private hire services.	Regular services which provide convenience for passengers.	Integrated into local transport networks.
Rural Air Mobility	Luxury private hire services.	Luxury private hire services, regional cargo and emergency service aircraft.	Regular services connecting nearby cities.	Connection and use exist between all UK cities, including more longer journeys.
Infrastructure inspections	Transition from demonstration to capability is very slow.	Developed network of BVLOS corridors allow long range inspections and maintenance.	Commonly used.	Large-scale use.
Emergency support services	Some services carried out by UAS, but these are limited.	Applications limited to less built-up areas due to privacy concerns.	Applications limited to less built-up areas due to privacy concerns.	Large-scale use.
Drone delivery	There is no drone delivery in this scenario due to privacy concerns.	Limited to rural areas due to airspace management policies.	Limited to rural areas due to airspace management policies.	Last-mile deliveries commonplace by 2030.

3.3 Infrastructure for scalable UAS and AAM operations

Significant infrastructure investment will be required to scale UAS and AAM operations in an integrated airspace. This includes BVLOS corridors, low level ground radar systems and digital infrastructure to accommodate unmanned traffic management (UTM). Physical infrastructure such as vertiports and UAS docking stations are included in the estimated of potential future revenues presented in this report, though costings for digital infrastructure are not included. Assumptions surrounding digital infrastructure and airspace competition are varied across scenarios to act as qualitative demand constraints. The scenario narratives presented in Annex B feature a description of the background infrastructure for AAM and UAS.

3.4 Outline of scenarios

This study developed four scenarios for the UK future flight market. This section summarises each scenario, developed from the narrative that emerged during the workshop process. The result of the scenario development is a description of market characteristics that were used to build the economic model in Section 4. The scenarios are:

Scenario 1: Low sector growth.
Scenario 2: Acceptance by business, but not by passengers.
Scenario 3: Technology breakthrough in the AAM market in the UK.
Scenario 4: High sector growth.

Sections 3.4.1 to 3.4.4 describe each scenario using extracts from the scenario narratives (presented in full in Annex B).

3.4.1 Scenario 1 summary: Low sector growth

Scenario 1 describes a lack of collective strategy and ambition between industry and government which results in low growth in the domestic future flight sector.

- **The UK context:** The UK government does not have a strong ambition to promote future flight. Future flight funding is dramatically reduced with funding being allocated to other sectors. In addition, regulators do not proactively develop new regulation that supports UAS and AAM operations, instead they react to international regulation changes at a slow pace.
- **The global context:** The global UAS and AAM markets are highly competitive with technology developments occurring at a faster pace than in the UK. Countries and regulators are competing to attract future flight manufacturers. This leaves the UK highly dependent on imports to support its future flight sector.
- **The UK's AAM market:** There is limited investment in AAM infrastructure. The only successful public use case is the movement of people between nearby major airports. Due to low levels of demand these services are expensive and irregular, creating an unaffordable and inconvenient service for passengers. Limited investment and unresponsive regulation forces AAM firms to leave the UK and set up business in countries with more favourable environments.
- **The UK's UAS market:** There is some public procurement of drones by Government, though little work has been done to establish a legal and regulatory framework for autonomy or reduce the public concerns around UAS. Drones are not widely used for deliveries, whilst they are used for some infrequent site inspections. The UK is heavily reliant on imported drones for the UAS activity that is occurring.

3.4.2 Scenario 2 summary: Acceptance by business, but not by passengers

In scenario 2, there exists a negative public view of the future flight sector due to setbacks in technology demonstrations. However, businesses do experience the benefits as efficient UAS services provide operational cost reductions. This results in regulation becoming tailored towards industrial operations.

- **The UK context:** The sector experiences demand from large businesses and some public sector procurement. Competition between businesses sparks an increase in demand for commercial UAS platforms. The public remain sceptical of UAS and AAM, resulting in low demand for use cases such as passenger transport and UAS deliveries.
- **The global context:** Across the world major businesses invest in UAS technologies and receive the benefit of integrating these systems into their day-to-day operations. In some other countries a more optimistic view on AAM prevails and they establish AAM for passenger use.
- **The UK's AAM market:** There is pessimism amongst the UK public for AAM. This translates to a limited number of passengers being willing to travel on an eVTOL. As a result, there are limited AAM routes with only a couple of scheduled passenger services in major cities and some logistics businesses make use of AAM for transporting cargo. This results in UK AAM manufactures relocating to access larger markets.

- **The UK's UAS market:** Industrial applications of UAS (e.g. site inspections, and emergency services support) increase as drone operations are integrated to become standard practice. This is supported by regulatory frameworks for BVLOS and autonomous drones. Despite this, last mile drone deliveries to consumers are limited due to privacy concerns. In general drone use cases which have a greater degree of interaction with the general public see slower demand growth than purely industrial applications.

3.4.3 Scenario 3 summary: Technology breakthrough in the AAM market in the UK

Scenario 3 is driven by a technological breakthrough in battery technology in the UK shortly after entry into service, increasing AAM availability and reducing costs. Whilst UAS is hindered with delayed regulation and entry into service due to public privacy concerns.

- **The UK context:** The UK government's appetite to future flight continues at its 2024 level, with the future flight challenge being renewed to provide the same level of funding. The UK government and regulators are reactive to public perceptions surrounding future flight. In this scenario the public are positive surrounding eVTOLs and AAM but have some concerns over privacy relating to UAS.

- **The global context:** Other countries do not experience the same technology breakthrough as the UK. To keep up with the UK, other countries begin to import battery technology from the UK to support their own AAM sectors. The global UAS sector continues to grow quickly with other countries regulating for different UAS capabilities earlier than the UK. The public trust in UAS in much higher in other countries allowing for less regulatory and legal debate.

- **The UK's AAM market:** The UK AAM market experiences a step change following the breakthrough in battery capabilities. Prior to the change passengers were willing to use AAM services but supply was constrained due to charging times and eVTOL range. Following the technology breakthrough supply constraints are reduced and allow for more regular flights over larger distances at a lower cost.

- **The UK's UAS market:** The public have some concerns over privacy relating to UAS use near their homes, though they do not actively oppose UAS use. This results in steady demand growth through the period for both drone deliveries and public sector drone use. Concerns over privacy delay the regulation and use of BVLOS UAS as the public feel more comfortable when the UAS operator is nearby.

3.4.4 Scenario 4 summary: High sector growth

In scenario 4, there exists a collective strategy and ambition between industry and government, which results in high growth in the domestic future flight sector. There are no major blockers by regulators or the general public.

- **The UK context:** The public and private sectors pursue ambitious growth strategies, making the UK a global leader in the future flight sector. The UK's leadership drives increased exports and industry growth, breaking down the industry's threats and barriers. The UK fully integrates AAM and UAS into the transport network. Regulators work proactively with industry, and government acts as both a source of investment and a facilitator of private investment.

- **The global context:** The global UAS and AAM market is highly competitive. Countries across the world are attempting to build an attractive ecosystem in order to attract future flight organisations. Companies are willing to be mobile and relocate to where the best combination of skill base, supply chain, and market exists to gain a competitive advantage.

- **The UK's AAM market:** AAM has become an integrated part of the UK transport network. The physical and digital infrastructure required for large scale AAM services has been developed, including vertiports and technology enabling integrated air traffic management. Major cities have multiple vertiports to connect outer city areas to inner city areas. It is also possible for passengers to travel between cities via eVTOL, as well as use eVTOLs to get to airports.

- **The UK's UAS market:** By 2050 there is a large-scale use of drones for a wide range of use cases. These include inspections of national infrastructure, emergency services initial response, surveillance and search and rescue operations. The national emergency response unit is supported by drone stations at multiple locations to improve search and response times. For the public it is normal to see drones flying in an integrated airspace.

3.5 Market characteristics

The market characteristics were designed to capture the size, shape and growth of future UK AAM or UAS markets. Whilst not an exhaustive list of influencing factors, these characteristics provide sufficient coverage of market activities to give reasonable estimates for the potential future market size and impact on the economy.

The market characteristics included factors that varied within scenarios (i.e. the economic factors associated with different MDAB states) and those that were modelled explicitly. The groups of market characteristics were:

- **Market definition:** The establishment of market segments to bound the market and create the initial conditions within each scenario prior to modelling. This detailed how the use cases were defined in each scenario.
- **Market activity:** The activity of future flight end users and regulators within the wider UK economy.
- **Trade:** The import of AAM and UAS components to facilitate UK market activity which reflected the strength of the global UAS and AAM markets relative to UK's.
- **Environment:** Environmental costs and benefits of UAS and AAM.

Table 3 defines each market characteristic in detail, as well as how the MDABs map across to the market characteristics. Each market characteristic was assigned a qualitative rating for each scenario, which set the basis for differentiation between scenarios in the economic modelling.

This table includes the model input values that are discussed in turn in Section 4. The next section describes how the qualitative ratings were used to inform the quantitative and scenario-specific differences in the modelling inputs.

Table 3: Overview of MDABs and model inputs

<table>
<tr><th>MDAB</th><th>Parameter</th><th colspan="2">Definition</th><th colspan="4">Assessment of market definition by scenario</th></tr>
<tr><td colspan="4">Market definition - This is used to create the initial conditions of the economic model.</td><td>Scenario 1</td><td>Scenario 2</td><td>Scenario 3</td><td>Scenario 4</td></tr>
<tr><td rowspan="2">Diversity of use cases
- Scenarios with higher use case diversity will have a greater percentage of market activity directed to ‘other’ use cases as there are more commercially viable UAS applications.</td><td rowspan="2">Use case split</td><td colspan="2" rowspan="2">The split of the business UAS market between the use cases outlined in section 3.2.1.

This is derived from drone user reports and public consultations for drone use.</td><td>Very Low
Use cases are limited due to demand and regulations.</td><td>High
Industrial applications for UAS become widespread.</td><td>Low
AAM is adopted but public interactions with UAS are limited.</td><td>Very high
Adoption into relevant industry and public use cases.</td></tr>
<tr><td>Model input
- Infrastructure inspections: 30%
- Emergency services: 30%
- Final-mile delivery: 0%
- Other: 40%</td><td>Model input
- Infrastructure inspections: 22%
- Emergency services: 25%
- Final-mile delivery: 2%
- Other: 51%</td><td>Model input
- Infrastructure inspections: 30%
- Emergency services: 22%
- Final-mile delivery: 5%
- Other: 43%</td><td>Model input
- Infrastructure inspections: 11%
- Emergency services: 19%
- Final-mile delivery: 10%
- Other: 60%</td></tr>
<tr><td rowspan="5">Social/public acceptance
- A higher level of social acceptance means more users are willing to use AAM.
Local planning laws
- Higher assessment of local planning laws leads to higher initial route coverage due to favourable planning for AAM.</td><td rowspan="5">Take up coefficient</td><td rowspan="5">The proportion of initial taxi distance substituted for AAM.

The take up coefficient is calculated by multiplying social acceptance by route coverage.</td><td rowspan="2">AAM social acceptance</td><td>Very low
AAM is viewed as a transport option for the wealthy.</td><td>Low
The general public are unsure of AAM vehicles.</td><td>High
AAM is viewed as a benefit to society.</td><td>Very high
AAM use is widely accepted and strongly endorsed.</td></tr>
<tr><td>Model input
12%</td><td>Model input
16%</td><td>Model input
22%</td><td>Model input
28%</td></tr>
<tr><td rowspan="2">Route coverage</td><td>Very low
Strong opposition to AAM infrastructure.</td><td>Low
Opposition from planners and local communities.</td><td>High
Planning laws begin to support AAM.</td><td>Very high
Planning laws are clear and support AAM.</td></tr>
<tr><td>Model input
1%</td><td>Model input
1.59%</td><td>Model input
2.27%</td><td>Model input
3%</td></tr>
<tr><td>Take up coefficient</td><td>Model input
0.12%</td><td>Model input
0.25%</td><td>Model input
0.50%</td><td>Model input
0.84%</td></tr>
</table>

MDAB	Parameter	Definition	Assessment of UAS market characteristics by scenario			
UAS market activity - The activity of the end users of UAS platforms.			**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
End user buy in - Scenarios with a higher level of end user buy-in will see higher demand. **Social/public acceptance** - Scenarios with a higher level of social acceptance will see a greater number of UAS platforms.	UAS demand growth (%)	The number of potential consumers who are willing and able to use UAS. Expressed as percentage increase in demand pear year. Scenarios 1 and 3 do not reach saturation due to later entry into service of BVLOS operations.	**Very low** Low buy in from end users.	**High** Businesses are interested in UAS.	**Low** Demand for UAS is limited.	**Very high** End users have high demand for UAS.
			Model input: 1.1% - 3.5% PA	Model input: 2.59% - 5% PA	Model input: 2.4% - 4% PA	Model input: 2.59% - 7% PA
	Autonomous UAS % of new sales	The proportion of new UAS sales that are allocated to autonomous UAS.	Model input: 2% - 4% of new sales	Model input: 5% - 10% of new sales	Model input: 4% - 7% of new sales	Model input: 10% - 35% of new sales
Future skills supply and demand - Scenarios with stronger supply of relevant skills will see a faster learning rate. **Long term R&D funding** - Scenarios with positive assumptions about R&D funding will experience innovative manufacturing which will increase the learning rate.	UAS platform prices	The retail price for a UAS platform. This acts as the price paid by the end user.	This is fixed as a real 2024 price and does vary across time in the scenarios according to the learning rate. Model inputs: Piloted UAS – £9500. Autonomous UAS – £19,997			
	UAS production learning rate	This represents the learning benefit from repeated UAS manufacturing. It follows Wrights learning curve law and results in lower production costs as more units are produced.	**Very low** Demand for skilled manufacturing workforce for UAS is low.	**High** Demand for skilled manufacturing workforce is driven by certain UAS use cases.	**Low** Workforce is prioritised on manufacturing AAM vehicles.	**Very high** UK AAM and UAS manufacturing workforce is highly skilled.
			Model input: 0%	Model input: 2%	Model input: 1%	Model input: 3%
Future airspace management - A positive assessment of airspace management means new capabilities can be integrated due to digital infrastructure. **Regulatory proactivity** - A higher level of proactivity means regulations are developed with industry	Capability entry into service	The entry into service year for BVLOS UAS and autonomous UAS capabilities.	**Very low** Future airspace management and regulation does not favour UAS.	**Low** Regulations relating to high demand use cases are developed.	**High** Regulators respond to public perception.	**Very high** An integrated airspace system with regulations developed alongside industry.
		BVLOS operations	Model Input 2032	Model Input 2029	Model Input 2030	Model Input 2026

MDAB	Parameter	Definition		Scenario 1	Scenario 2	Scenario 3	Scenario 4
UAS market activity - The activity of the end users of UAS platforms.				**Assessment of UAS market characteristics by scenario**			
buy-in. This allows capabilities to enter service earlier. **Regulatory timeliness** - Greater regulatory timeliness means that regulators respond quickly to changes in demand. This means capabilities can enter into service quicker.		Autonomous UAS operations		Model Input 2045	Model Input 2040	Model Input 2045	Model Input 2035
Diversity of use cases - Scenarios with a diverse set of use cases are more competitive. This leads to lower UAS contractor prices. **End user buy-in** - Scenarios with higher demand will see a more competitive and dynamics UAS sector. This keeps prices low as firms compete to retain market share.	UAS commercial revenues	The money paid to UAS contractors and service providers to deliver the use cases.	Infrastructure inspections (£/hour)	**Very high** Model input £150	**Low** Model input £60	**High** Model input £125	**Very low** Model input £50
			Emergency services (£/hour)	This is assumed as a fully public sector use case and therefore has no price attached. This is fixed across scenarios. Model inputs: £0			
			Drone delivery (£/delivery)	**Very high** Model input £10.65	**Medium** Model input £8	**Medium** Model input £8	**Very low** Model input £3.15
			Other use cases (£/day)	**Very high** Model input £550	**Low** Model input £300	**High** Model input £450	**Very low** Model input £275

MDAB	Parameter	Definition	Assessment of AAM market characteristics by scenario			
AAM Market activity - The activity of the end users of AAM			**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
End users buy in - Scenarios with a higher level of end user buy-in will see higher demand for AAM journeys. **Social/public acceptance** - Scenarios with a higher level of social acceptance will see a greater number of passengers willing to use AAM transport.	Demand growth (%)	The annual percentage increase in AAM passenger km travelled for each use case.	**Very low** AAM is seen as a transport option for the wealthy Model input: 0% - 1% PA	**Low** Public are unconvinced about AAM safety Model input: 0%-2.5% PA	**High** Passengers are positive towards AAM Model input: 0% - 6% PA	**Very high** End users have high demand for AAM Model input: 0%-8% PA
	Autonomous AAM share	The proportion of demand delivered by autonomous AAM.	Model input: 0%	Model input: 0% - 3%	Model input: 0% - 10%	Model input: 0% - 15%
Future skills supply and demand - Scenarios with stronger future skills supply will see a faster learning rate. **Long term R&D funding** - Scenarios with positive assumptions on R&D funding will have a higher learning rate. This is due to innovate manufacturing.	AAM prices	The rough order of magnitude cost to build AAM vehicles.	This is fixed as a real 2024 price and does vary across scenarios. This is used to represent current trends. The price will change according to the learning rate. Model inputs: RAM – £1,100,000; UAM – £220,000			
	AAM Learning rate	This represents the learning benefit from repeated AAM manufacturing. The follows Wrights learning curve law and results in lower production costs as more units are produced. Resulting in lower AAM costs.	**Very low** Low skills demand Model input: 3%	**Low** Skilled workers prioritise UAS Model input: 6%	**High** AAM attracts skilled workers Model input: 12%	**Very High** AAM workforce is highly skilled. Model input: 15%
Local planning laws - Positive planning laws will result in a greater proportion of AAM infrastructure being made up of larger vertihubs. This is due to less local opposition to large infrastructure	Vertiport capacity	The proportion of AAM infrastructure made up different vertiport sizes.	**Very low** Strong opposition to AAM infrastructure.	**Low** Opposition from planners.	**High** Planning laws support AAM but vary.	**Very high** Planning laws are clear and support AAM.
		Urban air mobility	Model Inputs Vertipad: 60% Vertibase: 40% Vertihub: 0%	Model Inputs Vertipad: 50% Vertibase: 50% Vertihub: 0%	Model Inputs Vertipad: 35% Vertibase: 60% Vertihub: 5%	Model Inputs Vertipad: 15% Vertibase: 75% Vertihub: 10%
		Regional air mobility	Model Inputs Vertipad: 30% Vertibase: 10% Vertihub: 60%	Model Inputs Vertipad: 25% Vertibase: 15% Vertihub: 60%	Model Inputs Vertipad: 10% Vertibase: 20% Vertihub: 70%	Model Inputs Vertipad: 0% Vertibase: 5% Vertihub: 95%

MDAB	Parameter	Definition	Assessment of AAM market characteristics by scenario			
AAM Market activity - The activity of the end users of AAM			**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Future airspace management - A positive assessment of airspace management means new capabilities are integrated due to improvements in digital infrastructure. **Regulatory proactivity** - A higher level of regulatory proactivity means regulations are developed with industry buy-in. This allows new capabilities to enter into service earlier. **Regulatory timeliness** - Greater regulatory timeliness means that regulators respond to demand. This means capabilities can enter into service quicker. **EV Charging readiness.** - Scenarios with a higher electric charging capacity will be able to support AAM transport at scale at an earlier stage.	Capability entry into service	The entry into service year for standard AAM and autonomous AAM capabilities.	**Very low** Regulations are unclear and not favourable to AAM adoption.	**Low** No fully integrated traffic management system due to low AAM uptake.	**High** Regulators respond to public perception.	**Very high** An integrated airspace system and regulatory approach meets the needs of AAM.
		AAM entry into service	Model Input 2035	Model Input 2032	Model Input 2028	Model Input 2027
		Autonomous AAM entry into service	Model Input 2060	Model Input 2045	Model Input 2039	Model Input 2035

MDAB	Parameter	Definition		Assessment of trade characteristics by scenario			
Trade – Proportion of UAS and AAM market activity that is supplied by imports.				**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Strength of domestic IP through R&D funding - Scenarios with a higher level of R&D funding will have a stronger UK manufacturing capability. This means less market activity is supplied by imports.	Percentage of market activity that is imported	The percentage of AAM and UAS market activity that is supplied by imported vehicles and components.	AAM imports	**Very high** Model input 50%	**Medium** Model input 30%	**Low** Model input 20%	**Very low** Model input 10%
			UAS platform imports	**Very high** Model input 90%	**High** Model input 75%	**High** Model input 80%	**Medium** Model input 60%
			UAS commercial imports	**Very high** Model input 30%	**Medium** Model input 20%	**High** Model input 25%	**Low** Model input 15%

MDAB	Parameter	Definition	Assessment of environmental characteristics by scenario			
Environment - Environmental costs and benefits of UAS and AAM in the UK.			**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
EV charging readiness - Scenarios with high charging readiness will be able to scale up electric vehicle operations at pace. This results in greater vehicle energy efficiency. **Future skills supply and demand** - A high skilled workforce will result in greater levels of innovation, resulting in technology breakthroughs that can improve energy efficiency. **R&D Funding** - Scenarios with strong R&D funding will commit more resources to developing more efficient vehicles.	Change in energy efficiency (%)	The amount of energy required to fly a given distance for AAM or UAS. This represents the change in energy efficiency throughout the forecasting period.	**Very low** There is limited R&D funding for AAM and UAS, and no investment in EV charging infrastructure.	**Low** There is minimal public EV charging infrastructure but there is a number of UAS ports for industrial operations.	**High** R&D in AAM leads to a technological breakthrough in batteries. There is investment in required infrastructure.	**Very high** Clear, extensive, co-leveraged R&D funding until 2050. There is investment in required infrastructure.
		UAS energy efficiency improvements	Model input 0%	Model input 5%	Model input 7.5%	Model input 15%
		AAM energy efficiency improvements	Model input 0%	Model input 2%	Model input 7.5%	Model input 10%

4 Economic modelling development

The future of flight economic model was developed using the market characteristics to produce a set of quantitative scenarios that were used to quantify the impact of each future flight scenario by 2050. This section outlines the model framework and provides justification for the values used to set the initial model conditions. Results and analysis are presented in section 5.

The model estimated the potential UAS and AAM market turnover along with the associated impact on the UK economy in terms of gross value added (GVA) and the employment supported by the market activities. Overarching key features of the model include:

- **Gross estimates of economic activity:** The model estimated potential market size by considering users switching vehicles or modes of transport to UAS and AAM. The revenues associated with switching were displaced from other areas of the economy and were not considered additional to the national economy. The model provides gross estimates of economic activity from UAS and AAM. This is due to a high degree of substitution from existing transport modes for AAM, whilst UAS use cases will be displace existing vehicles.
- **Uncertainty of future macroeconomic performance**: Sensitivity analysis was conducted on the results to reflect the uncertainty around macroeconomic performance. Three states of the future economy were used to reflect Office of budgetary responsibility (OBR) GDP projections (central), 0.5% growth per annum above (high economy) and 0.5% growth per annum below (low economy).

The model was split into sub-models for AAM and UAS to account for the different demand and supply factors for each future flight market. The key inputs within each model component are shown in figure 7 and discussed in turn. Based on the sources identified in each element description, the range of assigned values for the initial model conditions are presented in section 4.5.

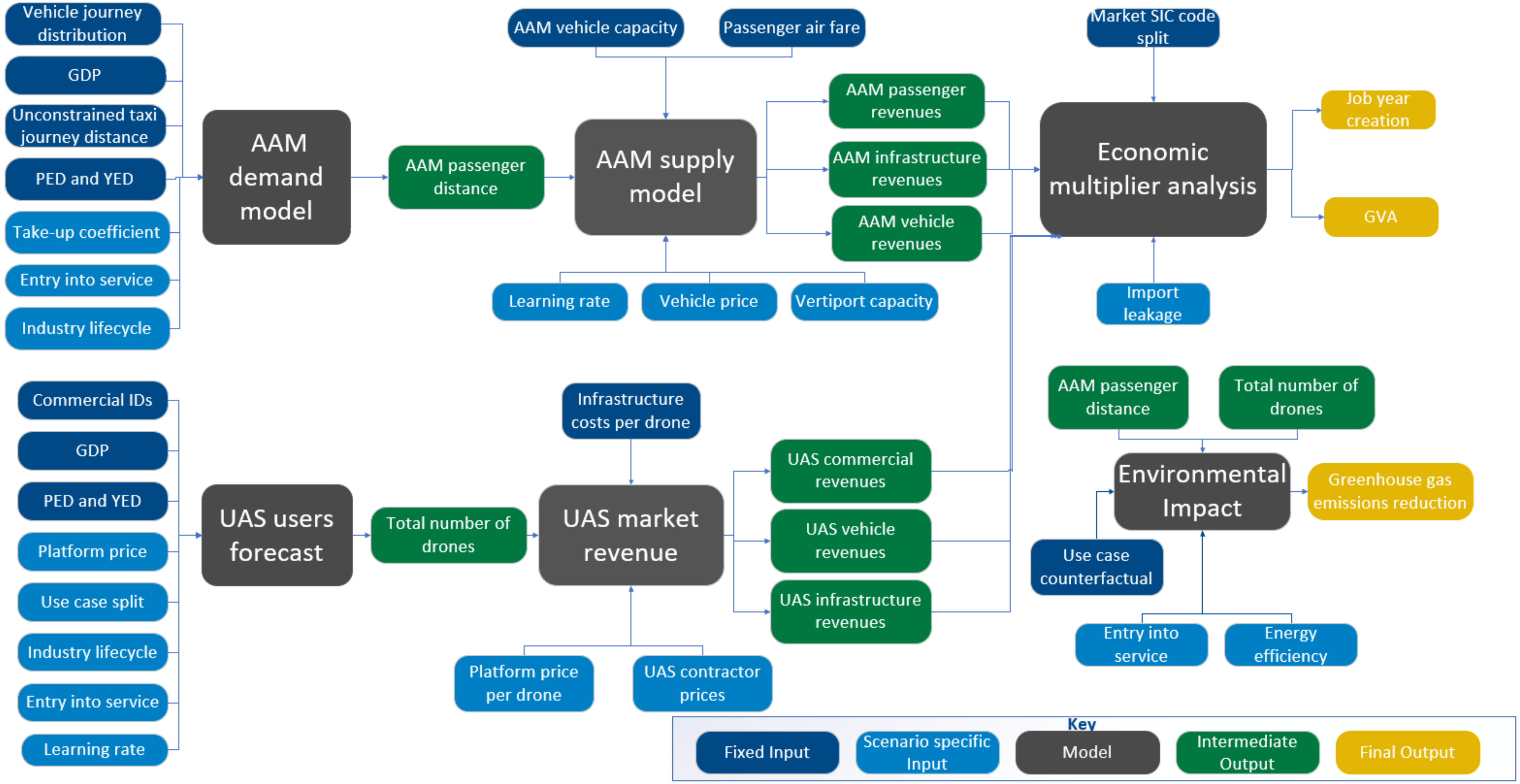


Figure 7 - Overview of the Future Flight Economic model

4.1 Uncrewed Air Systems (UAS)

Each scenario was defined by a set of demand assumptions based on social perception and willingness to use for UAS. These assumptions were combined with macroeconomic indicators and bespoke income and price elasticities to forecast UAS demand until 2050. The supply side of the market was constrained by the entry into service of BVLOS and autonomous UAS operations. The UAS model can be split into the following steps:

1. Define the market baseline
2. Estimate the number of UAS users
3. Calculate operational stock
4. Split by use case
5. Revenue calculations

4.1.1 Market definition

The key input to the demand model was the number of businesses with drone IDs. This study focused solely on the commercial part of the drone market with three specific commercial use cases. This was because the leisure market was assessed as close to maturity and was not expected to grow at the same high rates as the commercial market.

Information on the number of organisations with an operator ID was taken from the drone and model aircraft registration and education scheme database (DMARES). This represents the number of businesses who are able to use drones to deliver their services. From the commercial IDs, the scenario specific market splits were used to produce the number of IDs for the commercial use cases used to bound this study. The number of drones was calculated using the number of commercial IDs and the number of drones per business.

Number of businesses with operator IDs x drones per business = Today number of drones

This provided the baseline for the number of commercial drones in the UK. It was assumed in the model that autonomous drones replaced 2% - 25% of BVLOS drones during the introduction phase of the autonomous UAS lifecycle and 5% - 50% during the growth stage. The reason for the replacement of BVLOS and conventional UAS with autonomous UAS was due to cost and time savings for users.

4.1.2 UAS Users

The number of UAS users was forecast using the annual demand assumptions outlined in Table 4. The entry into service dates of key capabilities was a key parameter for regulatory and operational readiness and varied between the scenarios. Using the Future of Flight (FFIG) Action Plan,[16] the range of UAS capabilities into service was:

- Beyond visual line of sight operations: 2026 - 2031
- Autonomous UAS operations: 2030 - 2045

The entry into service year started the industry lifecycle with demand growing at the rate defined for each stage of the industry lifecycle. Each stage (introduction, growth, maturity, saturation) carried a different demand growth assumption. The model forecasted how the number of people with a drone ID will change over time. The industry lifecycle is used to define the demand growth at the end of each stage, with a linear growth curve fitted between each stage.

[16] UK Future of Flight Action Plan (publishing.service.gov.uk)

Table 4: Definition of UAS industry life cycle

Stage	Time period	UAS logic
Current trends	2024 – entry into service year for BVLOS operations	Current growth trends will continue as a pre-introduction phase.
Introduction	Entry into service + 3 years	FFIG action plan has 3 years between initial BVLOS operations and routine operations.
Growth	End of introduction + 10 years	The growth period in other studies of the UAS industry ranges from 8 to 12 years, with a significant compound annual growth rate at least until 2035. For this study we will assume the midpoint of 10 years.
Maturity	End of growth + 5 years	DfT drone forecasting model takes 5 years for commercial drone demand growth to fall from 0.5% to 0%. This reflects a period of slow growth maturity.
Saturation	End of maturity until 2050	This study ends in 2050. Scenarios 1 and 3 do not reach saturation due to later entry into service of BVLOS operations.

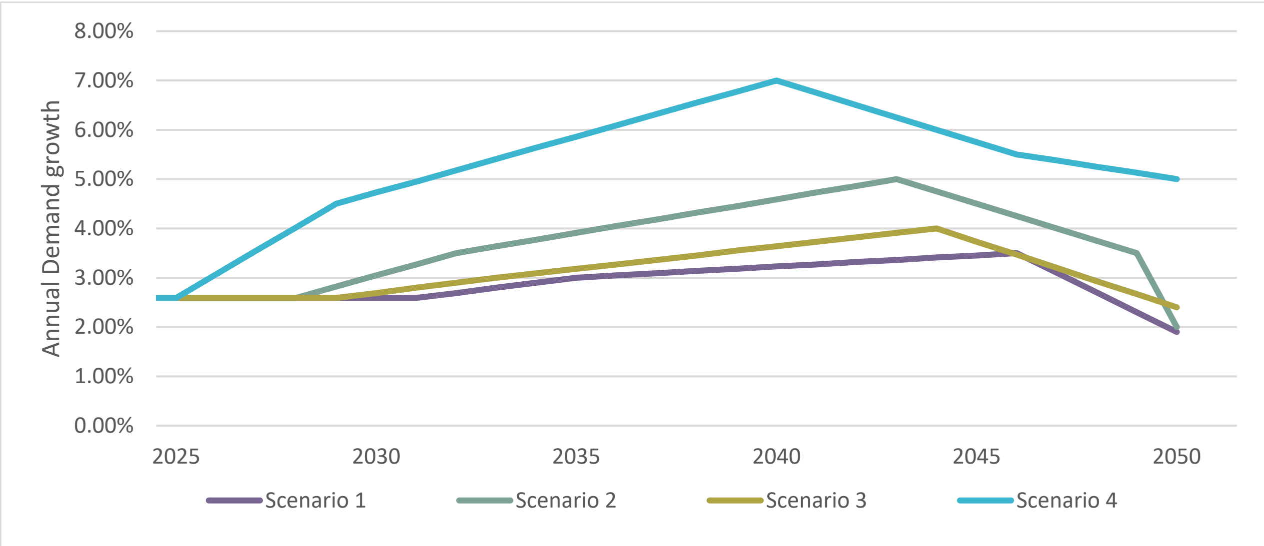


Figure 8: Annual demand growth for UAS

The annual demand growth, determined by the demand lifecycle, were input into the demand formula alongside GDP per capita growth, income elasticity of demand (YED), changes in platform prices and price elasticity of demand (PED). The elasticities were estimated through comparing the change in the number of drone IDs to GDP and income. This approach compared the percentage change in all DMARES IDs from before the end of COVID-19 lockdown. This is because there were many new registrations and delayed renewals following the end of lockdown. The in-year elasticity figures were averaged out over the period between 2019 and 2022 to establish a YED figure.

UAS platforms were assumed to have an asset life of three years,[17] which requires a UAS platform to be replaced every three years. For simplicity it is assumed that that there is a 100% retention in UAS users throughout the period. This means that the annual sales of drones is calculated as below:

Annual UAS sales = Replaced UAS platforms + New UAS sales

[17] FAA Remote ID final rule

The operational stock of drones was calculated by adding the new UAS sales to the operational stock in the previous year. This represents the total number of operational business drones in the UK.

The output from the UAS users model was the number of BVLOS and autonomous UAS for the commercial use cases in the UK each year until 2050. New UAS sales and operation stock was split by UAS use case:

The proportion of drone demand by use case varied between scenarios and covered the following range:

- Infrastructure inspections: 11% - 30%
- Emergency services support: 19% - 30%
- Drone delivery: 0% - 10%
- Other use cases: 40% - 60%

4.1.3 UAS platform and infrastructure revenue

Drone prices are highly uncertain, for this study they were baselined using a Monte Carlo simulation of 30 different drone prices as evidenced in Annex C dataset log 8. The most likely price value (50th percentile) was taken as the starting price estimate for a BVLOS platform, whereas the high price estimate (95th percentile) was used for the starting price for the autonomous UAS platform. Platform prices fall due to the learning effect which varied across scenarios. The learning effect was an application of Wrights learning curve, in which the production cost per unit falls as more units are produced.[18] The impact of the learning effect varied to reflect assumptions surrounding skills and R&D. The learning curve was applied from the baseline number of business drones and reflected the total number of sales made during the forecasting period. This reflected the production of drones up to 2050. The UAS learning curve was applied every 1000th unit for non-autonomous UAS, and for every 100th unit of autonomous UAS. This replicated a batched learning effect to capture the lagged implementation of process improvements in factories.

The UAS learning rate was varied to account for differences in the maturity of autonomous and non-autonomous platforms. The learning rate for non-autonomous UAS was halved to account for the maturity of the market. This reduces the learning effect in the early years of the forecast to represent that the non-autonomous UAS market has already experienced significant gains from learning.

Revenue from platform sales was calculated by the price of the drone multiplied by the number of drones. The infrastructure costs were based on the price for a drone dock and charger, assuming one dock is required for each UAS drone, with a more expensive dock required for an autonomous UAS. This price data was taken from manufacturer sales portals and expressed in 2024 prices. The total infrastructure costs were the price for the dock multiplied by the number of drones requiring docking. The initial prices for drones and docking ports used:

- Standardised drone price (piloted): £9,500
- Autonomous drone price: £19,997
- Piloted drone docking port: £5,776
- Autonomous drone docking port: £21,000

Overall, the UAS platform and infrastructure revenue model took the number of drones and multiplied these by the platform and infrastructure price to arrive at the revenue for each year.

[18] A review on learning effects in prospective technology assessment (uantwerpen.be)

4.1.4 UAS commercial revenue

This refers to the money received by UAS contractors to deliver their services. This was estimated for infrastructure inspections, final mile delivery and other use cases. Emergency services support was assumed to be a fully public use case and therefore will not attract commercial revenue.

Commercial revenue for infrastructure inspections was calculated by multiplying the hourly rate for infrastructure inspections by the number of hours flying. This was capped as there is a limited amount of UK infrastructure that can be inspected. Drone delivery revenues were calculated from the number of packages that could be delivered by UAS multiplied by a price per package. The revenue from other use cases was calculated by multiplying the number of operating days, based on the scenario demand assumptions, with a UAS contractor day rate.

The prices for all the use cases vary by scenario. In scenarios with low demand there is less competition meaning contractors can charge higher prices. Whilst scenarios with higher levels of demand will see lower prices due to increased competition. The price ranges are as follows:

- Infrastructure inspections: £50 - £150 per hour
- Emergency services support: Not monetised as this was assumed to be a fully public sector use case.
- Drone delivery: £3.15 - £10.65 per package
- Other use cases: £255 - £550 per day

4.1.5 UAS market outputs

The UAS market presented the number of UAS platforms operating across the UAS use cases until 2050, as well as forecasted revenues from platform sales, infrastructure sales and commercial revenue. The total value of platform and infrastructure sales revenue were carried into the economic impact model, whilst the number of drones per use case was input into the environmental impact model.

4.2 Advanced air mobility (AAM)

The AAM passenger market is currently non-existent due to low vehicle technology readiness levels (TRL), regulatory barriers, and insufficient infrastructure. To bypass the complications created from an absent market, the private hire taxi market was used a proxy to generate demand and supply forecasts. The taxi market was chosen because if AAM passenger services are introduced and grow to become a significant service, the two will become competitors. However, we acknowledge the taxi market does not fully capture the nuances of all AAM services. The AAM model is based on the following steps:

4.2.1 Define market baseline
4.2.2 Estimate passenger demand
4.2.3 Calculate vehicle and vertiport requirements
4.2.4 Calculate market revenue

4.2.1 Establishing initial market conditions

For this study the initial market conditions for AAM were derived from the demand for private hire taxis. The mean annual taxi passenger distance between 2002 and 2022 was used to capture overall taxi demand, excluding 2020 and 2021 data due the external impacts from COVID-19.[19]

As AAM is a new market and the substitution effect between AAM and taxis is unknown, an AAM take-up coefficient was generated for both rural air mobility (RAM) and urban air mobility (UAM). The take-up coefficient provided an initial estimation of how many taxi journey kilometres will be completed by RAM and UAM in the entry into service year. The take-up coefficient for the scenarios were the product of:

[19] Average number of trips, stages, miles and time spent travelling by mode: England, 2002 onwards

- **Willingness to use:** This represented the social acceptance level of AAM vehicles and passenger services. In 2022, 22% of the population held a positive view on AAM technology.[20] This was varied across scenarios to reflect differences in social acceptance.

- **Route coverage:** The estimated percentage of route coverage which will be completed prior to the introduction of piloted AAM capabilities. This was varied by scenario to reflect the qualitative assessment from the scenario narratives. Scenarios with a positive assessment of local planning laws had a higher degree of initial route coverage due to the ease of constructing vertiports locally.

To split the market by RAM and UAM use case, the unconstrained taxi demand was multiplied by the vehicle journey distribution of taxi journeys that could be replaced by RAM or UAM. The proportion of taxi journeys completed over 100km was adopted for RAM and the proportion of taxi journeys between 5 and 100 km was adopted for UAM. These definitions of UAM and RAM were based on the Brycetech AAM evidence review.[21]

This was used with the take-up coefficient to calculate the kilometres of taxi journeys that were substituted by RAM or UAM in the first year, the annual distance demanded for RAM and UAM.

4.2.2 AAM demand model

The AAM passenger distance demanded was forecasted using the annual distance demanded for RAM and UAM and various growth rates for the market as set out by the demand formula. The demand formula can be expressed as:

$\text{Passenger demand}_{year} = \text{Passenger demand}_{year-1} \times (1 + (\text{Demand growth}_{year} + (\text{GDP per capita growth}_{year} \times \text{YED})))$

AAM passenger demand followed an industry lifecycle in four stages to create an S-shaped curve. The current trend of no passenger demand for AAM continued until the entry into service year. Once AAM capabilities entered into service, the initial substitution away from taxi journeys occurred and then grew at the growth rate outlined in the introduction phase.

AAM demand growth peaked at the end of the growth period. Demand growth then slowed as the market matured and saturated up to 2050. The demand parameters were based on the wider AAM literature as well as assumptions made about the scale of market activity in each scenario. A linear forecast between the four stages of the lifecycle was used to determine the demand growth rate in each year. The AAM industry lifecycle is expressed in Table 5.

Table 5: AAM industry lifecycle

Stage	Time period	AAM logic
Current trends	2024 – entry into service year for eVTOL	This represents the current trend as eVTOLs are not yet in service.
Introduction	Entry into service + 3 years	FFIG action plan has 2 years between the initial passenger carrying piloted eVTOL operations and routine eVTOL operations. Plus, an additional year for the service to be sufficiently integrated.
Growth	End of introduction + 10 years	The growth period of the market in other studies of the AAM industry range from 8 to 12 years. For this study we will assume the midpoint of 10 years.
Maturity	End of growth + 5 years	PWC socio-economic study of AAM assumes slower growth in the period 2035 to 2040, which represents the end of their study.
Saturation	End of maturity until 2050	This study ends in 2050.

[20] Ipsos report (publishing.service.gov.uk)
[21] Advanced air mobility evidence review (publishing.service.gov.uk)

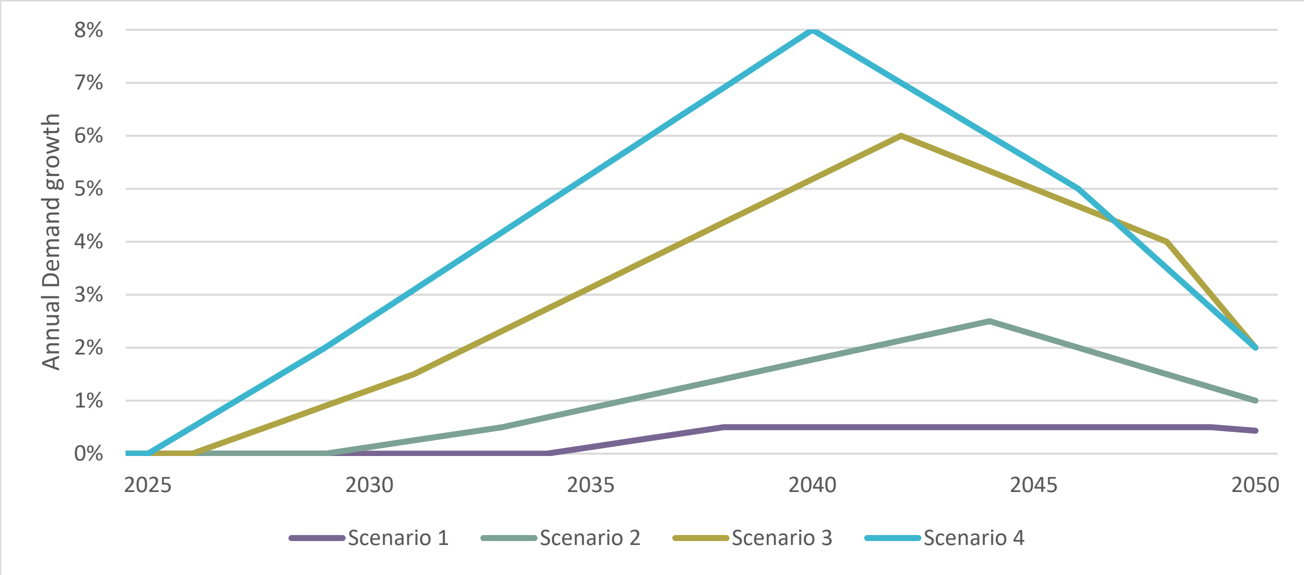


Figure 9: AAM annual demand growth

To estimate the potential size of the AAM market, the 2023 unconstrained taxi demand was calculated using the annual kilometres travelled by taxi per person in the UK from the DfT National Survey and ONS population statics. It is assumed that unconstrained taxi demand will grow with the estimated population growth rates.

The final stage split the demand for AAM between autonomous and piloted services. It was assumed that autonomous AAM replaces between 0% - 5% of piloted AAM journeys during the introduction phase of the autonomous AAM lifecycle and 0% - 15% during the growth stage. It was assumed that autonomous AAM replaces piloted AAM due to cost savings in the journey price because there is no need for a pilot.

4.2.3 AAM passenger revenues

The price per passenger per kilometre of £1.79 (2024 prices) was generated by taking the mean of seven price per passenger kilometre estimates of AAM travel.[22] The real price per passenger kilometre is assumed to remain fixed over the period. Real prices were kept constant because there was limited evidence to quantify how AAM firms will pass on manufacturing cost reductions to passengers. There was a high level of uncertainty relating to future market structures and market power as well as limited evidence on how consumers would react to price changes in AAM. It can be argued that as an industry matures, a lower price point will be realised. However, there was no reasonable evidence to support the magnitude of these price changes. Therefore, the real price per passenger kilometre remained fixed over the period.

By combining the passenger price per kilometre of travel with the RAM and UAM distance demand, annual passenger revenues were forecast up to 2050.

To capture additional passenger demand, the AAM distance travelled in the entry service year is seen as substituted as it related to initial take up. All remaining passenger distance is viewed as additional due to the establishment of an AAM transport modes.

4.2.4 Required AAM vehicles

The AAM supply model estimated the required number of RAM and UAM vehicles needed to meet the forecasted demand. The annual distance an AAM vehicle was calculated by multiplying the annual flight time, assumed as 6 hours

[22] Advanced air mobility evidence review (publishing.service.gov.uk)

per day,[23] and average AAM speed.[24] The number of RAM and UAM vehicles was calculated by dividing the annual passenger distance demanded by the annual distance each vehicle can travel.

4.2.5 AAM vehicle revenue

In order to estimate the real price of UAM vehicles, the mean of four UAM vehicle prices was used, prices were expressed in 2024 terms.[25] As no examples of RAM prices could be sourced, a multiplier of five was placed upon the UAM nominal price to represent the anticipated differences in UAM and RAM vehicle prices, as an RAM vehicle has a capacity five times greater than a UAM vehicle. By multiplying the annual required RAM and UAM vehicles with their respected prices the model forecasted vehicle revenue, the spending by industry on AAM vehicles.

There was also no data available for the price of an autonomous AAM vehicle, therefore the ratio of BVLOS UAS and autonomous UAS was used to provide an estimate on the price difference between piloted and autonomous AAM vehicles. The cost of AAM vehicles fell over the period because Wrights learning curve was applied to the prices. This occurred as production costs per unit falls as more units are produced.[26] The impact of the learning effect varied according to each scenario to reflect assumptions surrounding AAM skills. The impact of the learning curve is expressed through the below formula (the same formula applies for the UAS learning curve):

$$C = aX^b$$

Where:

C = Cost to produce additional unit

a = Cost of the first unit

X = cumulative units of production

b = Learning rate – this was varied by scenario based on assumptions around R&D and the skills of the UK future flight sector.

4.2.6 Required AAM vertiports.

The model defined three types of vertiports which were based on the McKinsey report on AAM infrastructure:[27]

- **Vertipad:** the smallest type and typically located in suburban or rural locations. A vertipad has one landing/ take-off pad and two parking spaces.
- **Vertibase:** medium-sized vertiports likely located in suburbs or major commercial areas. A vertibase has three landing / take-off pad and six parking spaces.
- **Vertihubs**: the largest structure located within core urban areas. A vertihub has ten landing/ take-off pad and twenty parking spaces.

All three vertiport types had an associated number of pads used for landing and take-off and an additional number of spaces used for parking, charging and maintenance. The model assumed that the total number of parking, charging and maintenance spaces must be equal to the total number of AAM vehicles, to accommodate all vehicles. The model made assumptions on the type of vertiports that RAM and UAM vehicles are likely to need.

The weighted average number of RAM and UAM spaces per vertiport and the number of vehicles required to fulfil annual distance demanded were used to calculate the number of vertiports needed each year between 2024 and 2050. This is varied by scenario. Scenarios with a positive assumption on local planning laws will have a larger proportion of

[23] 'The first eVTOLs will form a beachhead industry' and there is nothing wrong with that | Revolution.aero
[24] Advanced air mobility evidence review (publishing.service.gov.uk)
[25] Order | Pivotal
[26] Insert the title here (uantwerpen.be)
[27] To take off, flying vehicles first need places to land

the AAM network covered by vertihubs and a smaller proportion of vertibases. This is because there is less opposition to large AAM infrastructure from local planners and communities.

4.2.7 AAM vertiport capital and operational expenditure

The weighted average of capital and operational expenditure costs associated with each type of vertiport were multiplied by the RAM and UAM breakdowns to formulate a weighted average capital expenditure for RAM and UAM vertiports in 2024 prices.[28] This was multiplied by the annual required vertiports for RAM and UAM vehicles to forecast capital expenditure for AAM services. The capital expenditure only applies to the year in which the vertiport is built, whereas operational expenditure applies to all vertiports operating each year. These cost estimates exclude replacement CAPEX due to the scale of costs and the complexity of the estimation.

4.2.8 AAM market revenues

AAM market revenues was the sum of passenger revenues, vehicle revenue, vertiport capital expenditure and vertiport operational expenditure. This represented the spending associated with delivering an AAM transport service in the UK. This market revenue was an input into the economic multiplier analysis.

4.3 Contribution to the UK economy (GVA and employment)

The UK wide impacts arising from forecasted AAM and UAS revenues were estimated by multiplier analysis using the Office for National Statistic (ONS) input-output analysis, which gives a snapshot of an economy at a given point in time. The market revenue forecasts, provided by the economic model, estimated the potentiation future market transactions that include:

- UAS platform, infrastructure and commercial revenues.
- AAM vertiport capital expenditures, vehicle expenditures and passenger service revenues.

The estimated total impact on UK gross value added (GVA) and job-years created from these market transactions was derived from the component flow of transactions throughout the economy: the direct, indirect and induced impacts. The key assumptions made during this estimation which are not mentioned elsewhere in the report include:

- **Leakage:** While a significant proportion of AAM vehicles will be satisfied by firms in the UK, there is a significant proportion of UAS demand satisfied by firms outside the UK. The proportion of which is based on the current location of the firms producing or developing UAS and AAM vehicles. The leakage assumption was varied according to the import market characteristic for each scenario, the leakage ranges were:
  - UAS platform and infrastructure imports: 90% - 60%
  - UAS commercial imports: 30% - 15%
  - AAM: 50% - 10%

  The UAS global market share held by DJI (a monopoly UAS vehicle producer) was used as an approximation for initial UAS industry imports.[29] For AAM, it was assumed that the market export/import proportions would be similar to that of the wider UK aerospace sector.[30]

- **Expenditures by industry**: Each expenditure type was mapped to a UK industry (SIC, 2007) based on the registration information of the companies likely to undertake the respective activity. These were derived from the AAM evidence review's additional datasets. The industries included were:

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[28] To take off, flying vehicles first need places to land (mckinsey.com)
[29] The Top 25 Drone Companies in 2024 - Drone U™ (thedroneu.com)
[30] United Kingdom - Market Overview (trade.gov)

Table 6: Split of market revenue by UK industry.

	Air and spacecraft and related machinery	Air transport services	Computer, electronic and optical products	Architectural and engineering services; technical testing and analysis services	Other professional, scientific and technical services	Services to buildings and landscape
UAS Platform revenue	60%	-	40%	-	-	-
UAS Infrastructure revenue	50%	-	50%	-	-	-
UAS commercial revenue	-	-	-	20%	45%	35%
AAM Passenger Revenue	-	100%	-	-	-	-
AAM Vehicle Revenue	100%	-	-	-	-	-
AAM Vertiport expenditures	25%	75%	-	-	-	-

4.3.1 Estimating potential GVA and job-years impact

The impact estimation used the major spending flows within an economy including:

- Final demand (i.e. consumer spending, government spending investment and exports to the rest of the world);
- intermediate spending patterns (i.e. what each sector buys from every other sector though the supply chain);
- how much of that spending stays within the economy; and
- the distribution of income between employment and other forms such as corporate profits.

The ONS input-output tables are a matrix representation of the UK's interconnected economy.[31] This was used to create multiplier effects for each industry by tracing inter-industry transactions – that is the value of goods and services that are needed (inputs) to produce each pound sterling of output for the individual sector being studied.

The direct suppliers' procurement spending was broken down to identify the contribution to GVA by industry. Each of the industries in the direct channel had the revenue split between UK taxes on products, imports (including overseas taxes but net of UK taxes) and net-of-tax domestic supplies, based on ratios in the ONS input-output tables. The GVA of the entire supply chain could then be worked out, using the share of GVA in each industry's output. The resulting indirect and induced GVA impact estimate was calculated using Type II multipliers calculated by the Leontief method, using the ONS input-output analysis.

The number of job-years supported by the GVA contribution to the UK economy was calculated using the forecast GVA per job values, taken from ONS Annual Business Survey results. To note these are gross estimates as much of the future flight economic activity comes from displacement and substitution.

The total GDP and employment impacts are the sum of the separate direct, indirect and induced impacts. The economic impact results in this report are gross estimates and are undiscounted.

[31] UK input-output analytical tables: product by product - Office for National Statistics (ons.gov.uk)

4.4 Environmental benefits

To estimate the environmental impact that UAS and AAM adoption may have on the UK, the model monetised the impact on carbon dioxide emissions. The estimates were compared with a counterfactual, for UAS the counterfactual assumes UAS drones continue to be used and grow at the current trends, and for AAM the counterfactual assumes the AAM service is not provided. This allowed the net benefit of UAS and AAM technologies to be calculated.

4.4.1 UAS environmental impact

4.4.1.1 Summary

The UAS environmental impact was separated to fit the three use cases for UAS that were investigated in the economic model which were infrastructure inspections, emergency services support and last mile drone delivery. However, within infrastructure inspections and emergency services two specific uses were identified as a direct substitution creating a significant environmental impact, power line inspections and search and research (SAR). The UAS environmental estimate is limited to infrastructure inspections, emergency services support and last mile drone delivery due to the fidelity of the use cases. Significant environmental benefit is anticipated from the "other use cases" which have been fully defined in this report.

4.4.1.2 Infrastructure inspections

Currently, the National Grid, Network Rail and National Highways all use fleets of helicopters to patrol a combined distance of 68,200km of infrastructure each year.[32,33,34] The initial number of drones for infrastructure inspections in 2023 was used to calculate the annual distance travelled by these drones by multiplying the number by annual running hours and average drone speed.

Each year the annual distance patrolled by drones increased by the number of infrastructure inspection drones as forecast in the model. The increase in percentage change of annual distance patrolled by drones, decreased the annual distance patrolled by helicopters as it was assumed that UAS drones substitute the role of helicopters in the use case. It was assumed that helicopters remain powered by fossil fuels, as sustainable aviation fuels were not included in the scope of this study.

The annual distance patrolled by each vehicle was used to calculate the amount and cost of CO_2 emissions produced by combing the helicopter CO_2 emissions per kilometre of inspection and kWh per kilometre of drone activity with the DfT's TAG workbook the model estimates the monetary impact of CO_2 emissions for inspecting the UK's power grid, railways, and highways. [35,36,37]

The counterfactual had the same 2023 figure for annual distance patrolled for UAS drones and helicopters however the annual increase in UAS drones was fixed to the initial trend rate of growth in the market, 2.59%. The percentage change in growth in UAS drone distance, decreased the distance travelled by helicopter. The annual distance patrolled by each vehicle was used to calculate the amount and cost of CO_2 emissions.

As the potential distance of infrastructures inspections was constrained it was necessary to cap the market. In this model the market was capped at 368,000km of UAS infrastructure inspections which represented all of the UK's powerlines, railways, and highways being surveyed once per month by UAS. This market cap was also applied to UAS commercial revenues.

[32] What do National Grid's helicopters do? | National Grid Group
[33] Rail Infrastructure and Assets 2020-21 (orr.gov.uk)
[34] Roads we manage - National Highways
[35] How much CO2 is saved by switching from helicopters to drones for power line inspections? (airpelago.com)
[36] Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery - PMC (nih.gov)
[37] TAG data book - GOV.UK (www.gov.uk)

4.4.1.3 Emergency services support

The benefit of drones for SAR was assumed to be in the searching phase of search and rescue. Therefore, any rescue or transportation hours from the SAR helicopter statistics in 2023 were removed before being input into the model.[38] This left the number of helicopter hours for search as the starting point. The starting point for drone SAR flying hours was a regional estimate for the SAR team in Wales in 2023, scaled up to cover the whole of the UK.

The SAR hours for UAS increased each year by the number of new SAR drones forecast by the model. The percentage increase in SAR hours completed by drones, decreased the SAR hours completed by helicopters until it was fully substituted.

The counterfactual had the same start points, and as in the infrastructure inspections model, the number of new SAR drones increased at the current trend rate of 2.59%. The number of SAR hours completed by helicopter and drone were used to calculate the amount and cost of CO_2 emissions.

4.4.1.4 Last mile drone delivery

The UAS last mile delivery use case compared UAS vehicles to a light goods vehicles (LGV) counterfactual. As last mile drone delivery was not an actual service in 2023, the counterfactual environmental impact model was built first and then had UAS delivery substituted in.

The counterfactual model combined DfT's estimates for the number of commercial LGV used for delivery purposes and assumptions from DfT's TAG Workbook to estimate the carbon emissions for each fuel type of LGV.[39] This was adjusted for expected fuel efficiency improvements and the transition towards electric LGVs by 2050.

To build the UAS drone delivery model, the number of vehicles required to deliver the same volume of parcels was calculated depending on delivery efficiency with UAS vehicles expected to deliver 8 packages per hour,[40] whilst LGVs were able to deliver 20.5.[41] The number of new UAS platforms each year substituted the equivalent number of LGVs from delivering parcels. This produced a scenario where last mile deliveries were completed by LGVs and UAS drones.

Data estimating the CO_2 emissions per package delivered per vehicle fuel type was used to quantify the impact of changes in emissions from the introduction of drone delivery.[42] This was multiplied by the annual number of packages delivered by each fuel type to calculate the amount of emissions per vehicle type which allowed the total cost of emissions to be calculated.[43]

4.4.2 AAM environmental impact

To estimate the environmental impact that the adoption of AAM passenger services had on greenhouse gas emissions, the emissions from taxi and Public Service Vehicles (PSV) services covering the annual passenger distance estimated in the model was compared to the emissions from UAM and RAM services.

Greenhouse gas emissions and its social cost were estimated using an in-year approach. By including forecasted changes in vehicle efficiency and vehicle kWh per passenger kilometre, the model estimated the total in-year energy usage of RAM and UAM vehicles. The energy usage was converted into kilogram of CO_2 emissions and the amount of CO_2 produced by AAM services was calculated. The cost per tonne of CO_2 emissions was used to estimate the social cost.

The counterfactuals for CO_2 emission were estimated using the same method however, AAM vehicle usage was assumed to be non-existent throughout. The proportion of electric taxis increased throughout the period as forecast in the TAG datebook.

[38] Search and Rescue Helicopter Statistics: Year ending March 2023 - GOV.UK (www.gov.uk)
[39] Van statistics: 2019 to 2020 - GOV.UK (www.gov.uk)
[40] Drone and deliver (aerosociety.com)
[41] Yodel (yodelopportunities.co.uk)
[42] Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery - PMC (nih.gov)
[43] UK parcel shipping: annual volume 2013-2023 | Statista

4.5 Model input values

To quantify the economic impact of AAM and UAS in the UK, the market characteristics were assigned a quantitative value to bound the economic model. A number of these characteristics vary by scenario. These variable parameters were combined with a set of fixed parameters to define an economic model.

The quantitative parameters were defined during the horizon scan and refined throughout the scenario development process to establish the range that should be applied to each scenario. The presented parameters across the scenarios represent the feasible range that these parameters may take in the future.

The state of the broader UK economy has not been varied by scenario, instead GDP per capita growth was varied to present the scenarios under different macroeconomic conditions. In addition, as the model is UK focused, the state of the world economy and the global future flight market were not directly modelled.

The model input parameters are presented in Table 3, located in section 3.4. The parameters were used to define the economic and environmental models for analysing the future potential market size under each scenario.

5 Scenario-based economic analysis

5.1 Summary

This section details the results of the economic analysis to quantitatively compare the scenario-based outcomes for the UAS and AAM markets until 2050. The analysis used the categories of market characteristics—market activity, trade and environment—to produce:

- **Economic results:** GVA, revenue and employment for each scenario.
- **Environmental results: M**onetised greenhouse gas benefits for each scenario.

The size of the UAS and AAM markets using cumulative revenue by year until 2050, are reported in Figure 10 and Figure 11.

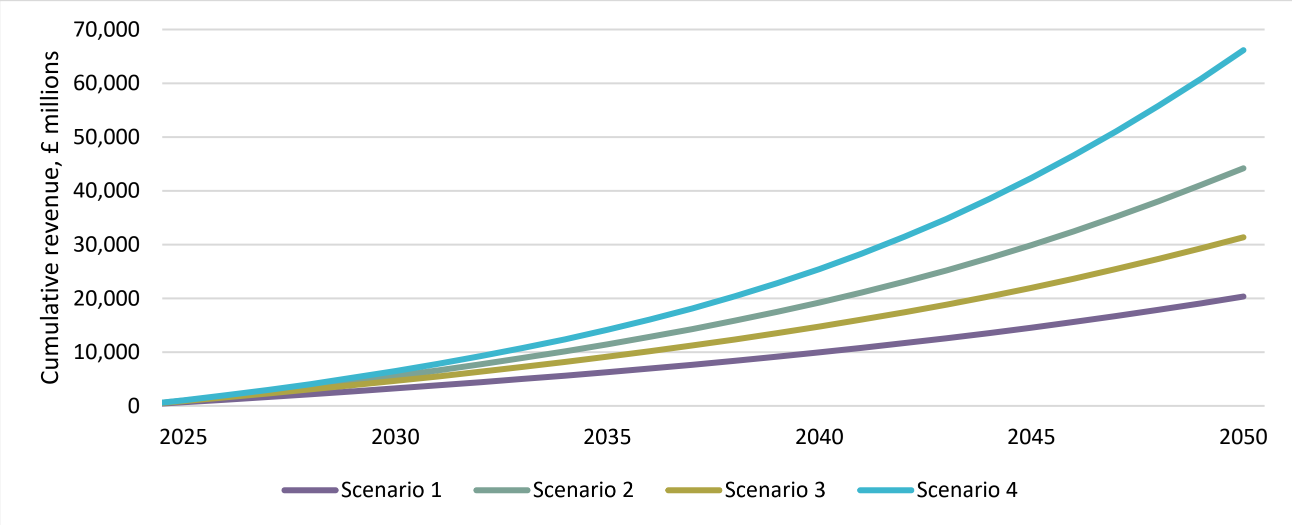

Figure 10: Cumulative UAS market revenues

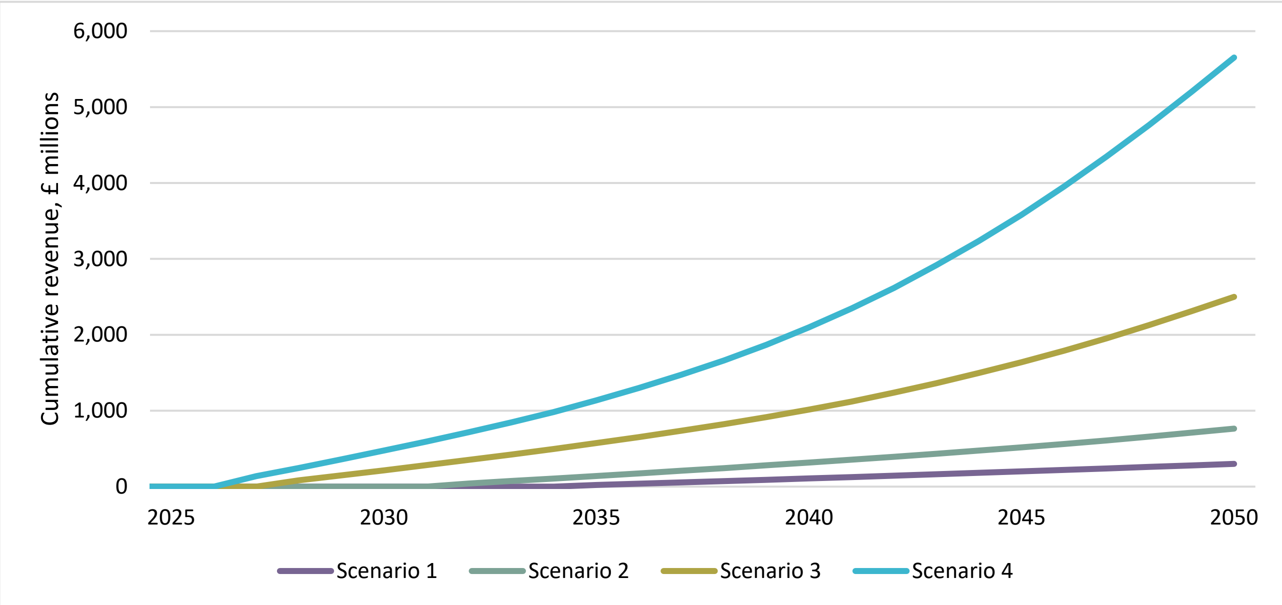

Figure 11: Cumulative revenues of the AAM market

The cumulative UAS revenue is expected to range between £20.3 billion and £66.2 billion, with high revenue growth under scenarios 2 and 4, and low revenue growth under scenarios 1 and 3. During peak demand, UAS annual revenue ranges from £1.3 billion to £5.4 billion per year. It is interesting to note that the potential UAS cumulative revenues generated by scenarios 1 and 3 are similar despite having different quantitative inputs. This is driven by the demand growth cycles and import assumptions for the two scenarios as they define low levels of growth and then allow most of the economic impact to leak from the UK economy.

The AAM market has substantially more variation between scenarios. The cumulative revenue reaches as high as £5.7 billion in scenario 4, whilst for scenario 1 and 2 cumulative revenue is just £300 million and £764 million, respectively. These figures present reasonable upper and lower bounds for the size of the AAM market from 2025 to 2050.

The annual revenues for the UAS and AAM markets are presented in Figure 12 and Figure 13 They illustrate how differently the two markets are expected to grow with UAS following a standard boom and then market saturation whilst AAM experiences an initial burst in revenue due to investments in infrastructure before following standard demand growth.

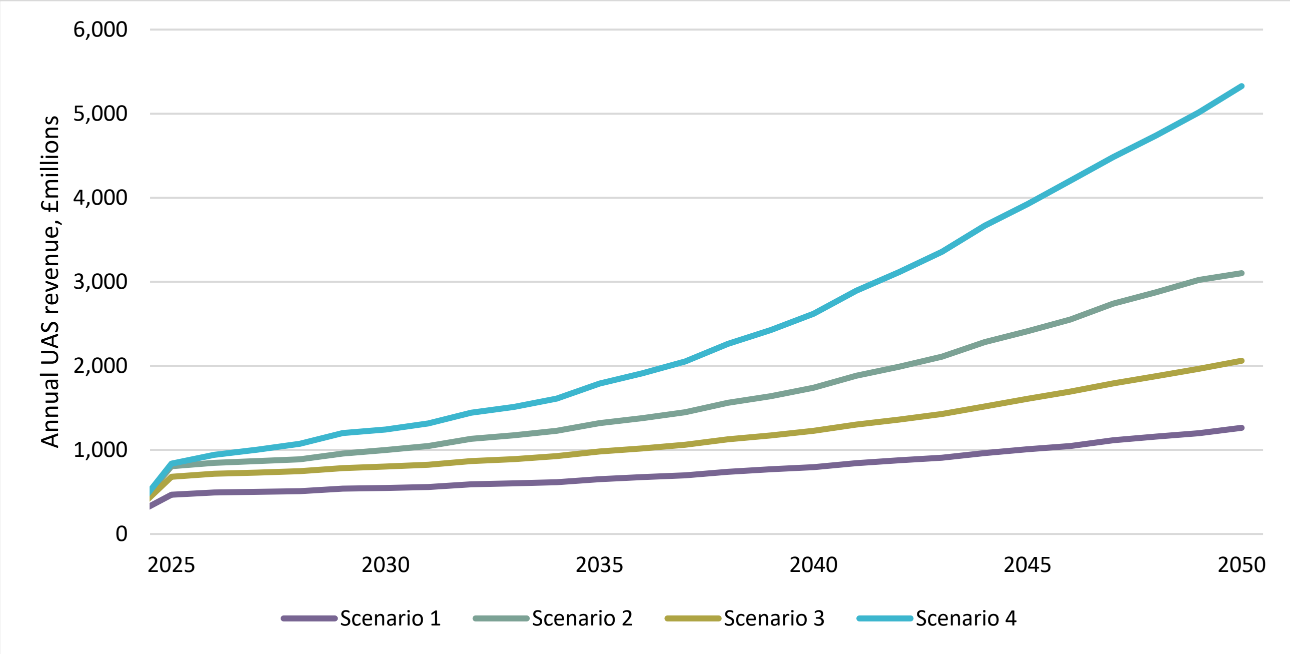

Figure 12: Annual UAS revenues

The contraction of UAS annual revenue growth towards 2050 is due to the industry maturing and reaching saturation, during this industry lifecycle phase demand growth slows and revenues fall. This is more prevalent in scenario 3 where demand growth contracts at a greater rate than the other scenarios. The range of annual revenue between the scenarios is due differing degrees of end user buy-in and social acceptance across scenarios impacting demand. This is particularly evident between scenario 2 and 3, where the fundamental difference is a change in the end user buy in for commercial UAS users.

AAM market revenues are driven by infrastructure investment in vehicles and vertiports as large amounts of spending are required to build and operate a vertiport which stores and charges the vehicles. In addition, the entry into service provides a jump start to the market as is evident in Figure 13 with the AAM demand beginning to grow. This parameter has a significant effect on the result as there is no passenger market for AAM until the capability enters service, however it should be noted that the scenarios which see the fastest revenue growth are those scenarios where social acceptance and end user buy in is high. This suggests that timely regulation must also be supported by strong public relations campaigns and communication to end users and other stakeholders.

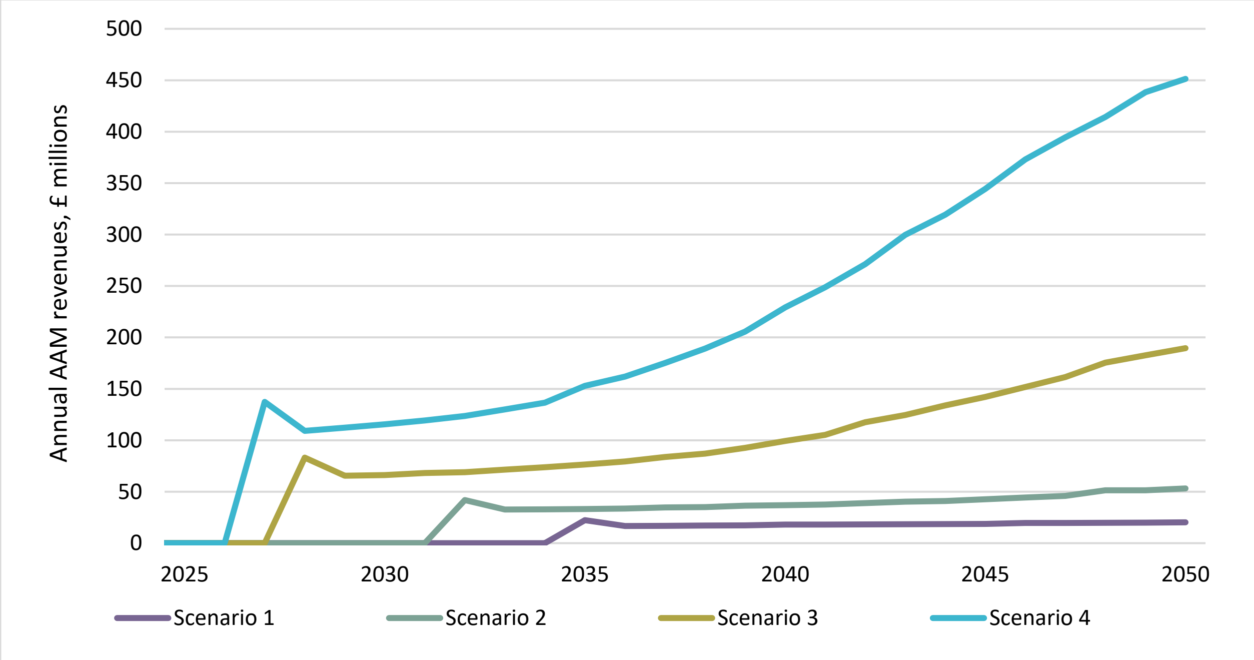

Figure 13: Annual AAM revenues

Annual revenue experiences a spike following entry into service of eVTOLs due to sharp increases in vehicle and vertiport expenditures. The second smaller spike in annual revenues follows the entry into service of autonomous eVTOL operations. Scenario 1 does not experience this as autonomous eVTOLs do not enter service during the period because of low public acceptance for autonomous vehicles.

Figure 14 and Figure 15 show the GVA contribution of AAM and UAS up to 2050, this is presented cumulatively and annually. Cumulative gross GVA contribution ranges from £24.4 billion to £103 billion by 2050. Annual GVA contributions spike following entry into service of AAM, and slow towards the end of the forecast period due to market maturity and saturation.

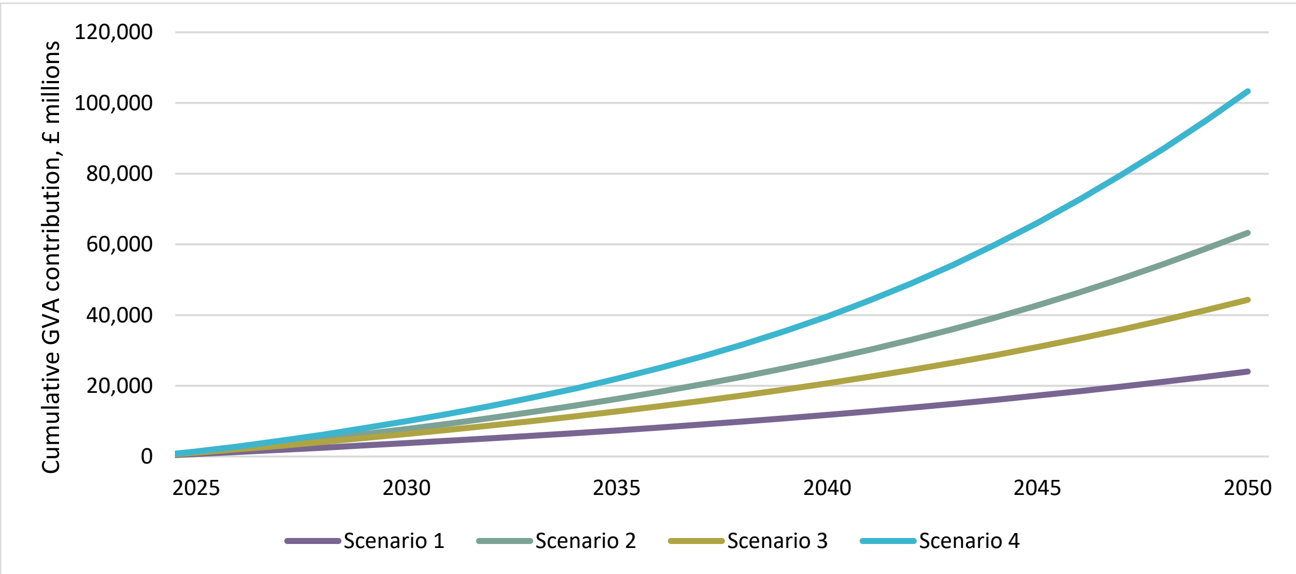

Figure 14: Cumulative GVA contribution of the UAS and AAM markets

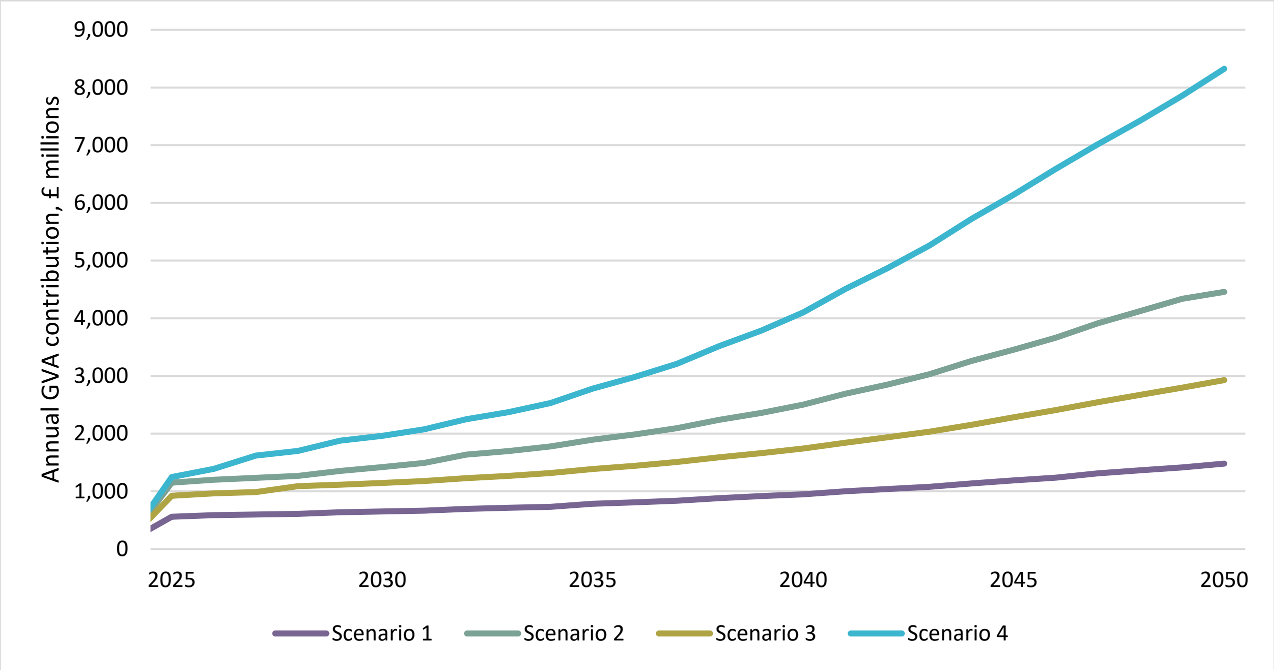

Figure 15: Annual GVA contribution of UAS and AAM markets

Job-years created by the UAS and AAM markets, shown in Figure 16 and Figure 17, reflect the trend in annual revenues for these markets. All scenarios forecast job creation from the adoption of UAS and AAM technologies. Under scenario 4, UAS and AAM create the largest number of job-years – more than 3 million across the period – whilst scenario 1 creates 611,000. The sectors of the economy most affected by future flight are air and spacecraft related manufacturing, air transport services and computer, electronic and optical products.

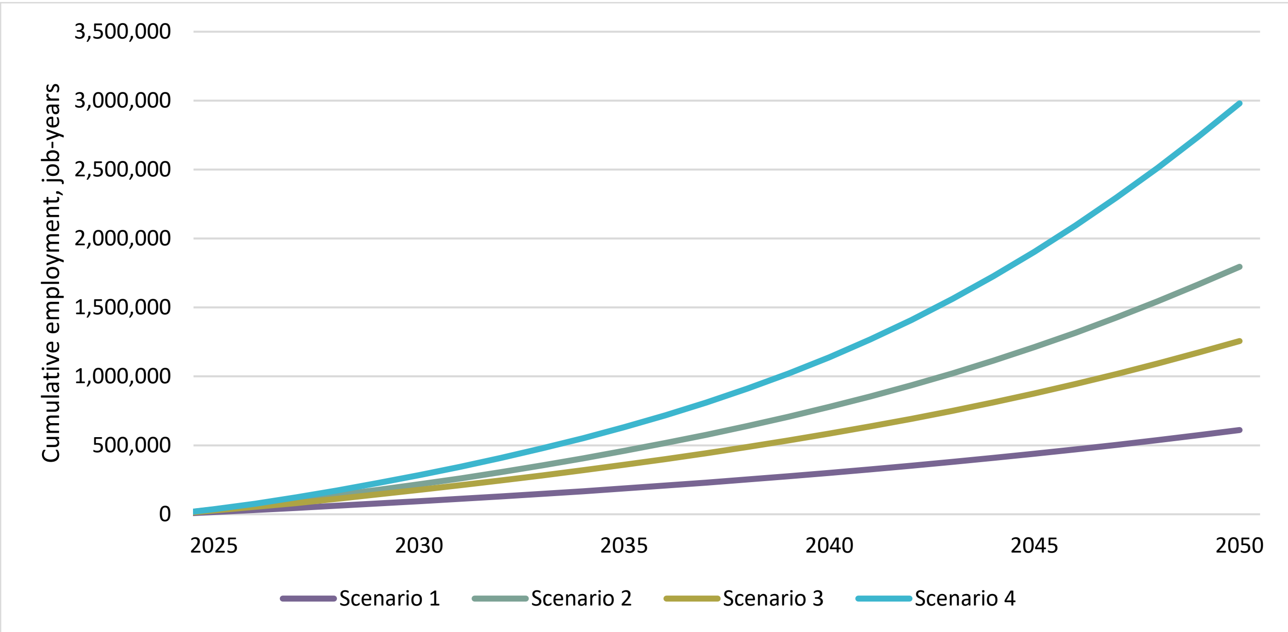

Figure 16: Cumulative employment in the UAS and AAM markets

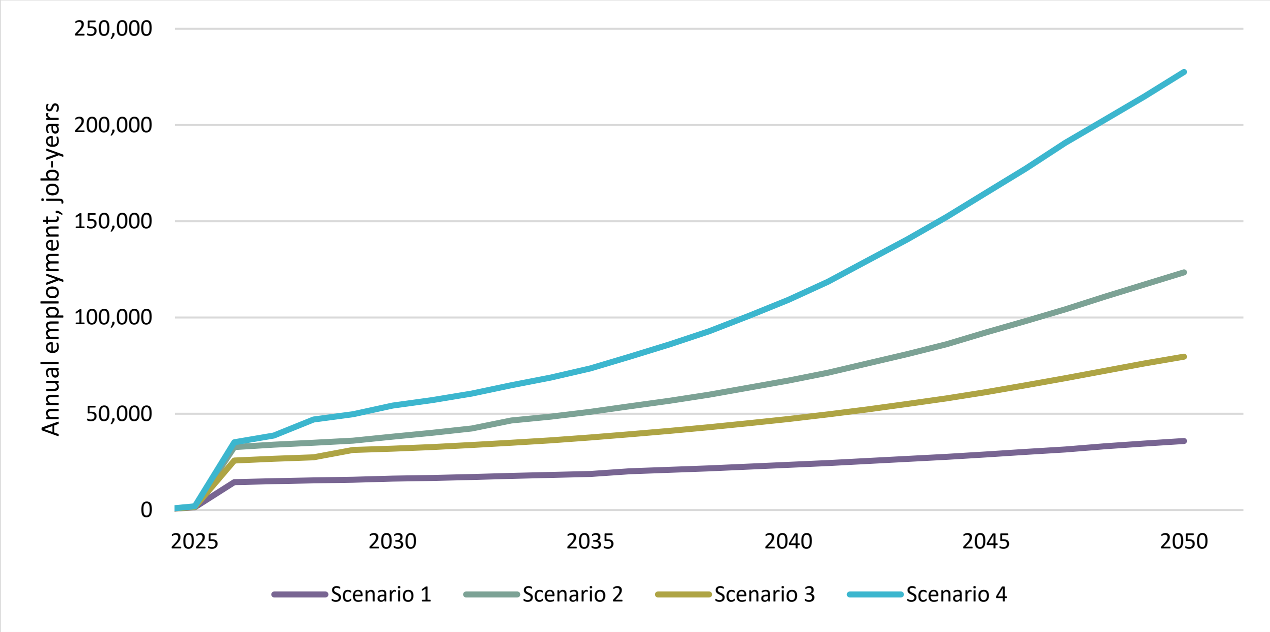

Figure 17: Annual employment in the UAS and AAM markets

Figure 18 presents the cumulative environmental impact of AAM and UAS over the period. These impacts are the additional social benefits occurring from the transition way from the existing fossil fuel-based vehicles to future flight ones for the use cases. The model takes into account TAG data book assumptions for the proportion of road vehicles forecast to be electric between 2024 and 2050.[44] The social benefits produced by the reduction in greenhouse gas emissions range from £10.2 million in scenario 1 to £124 million in scenario 4.

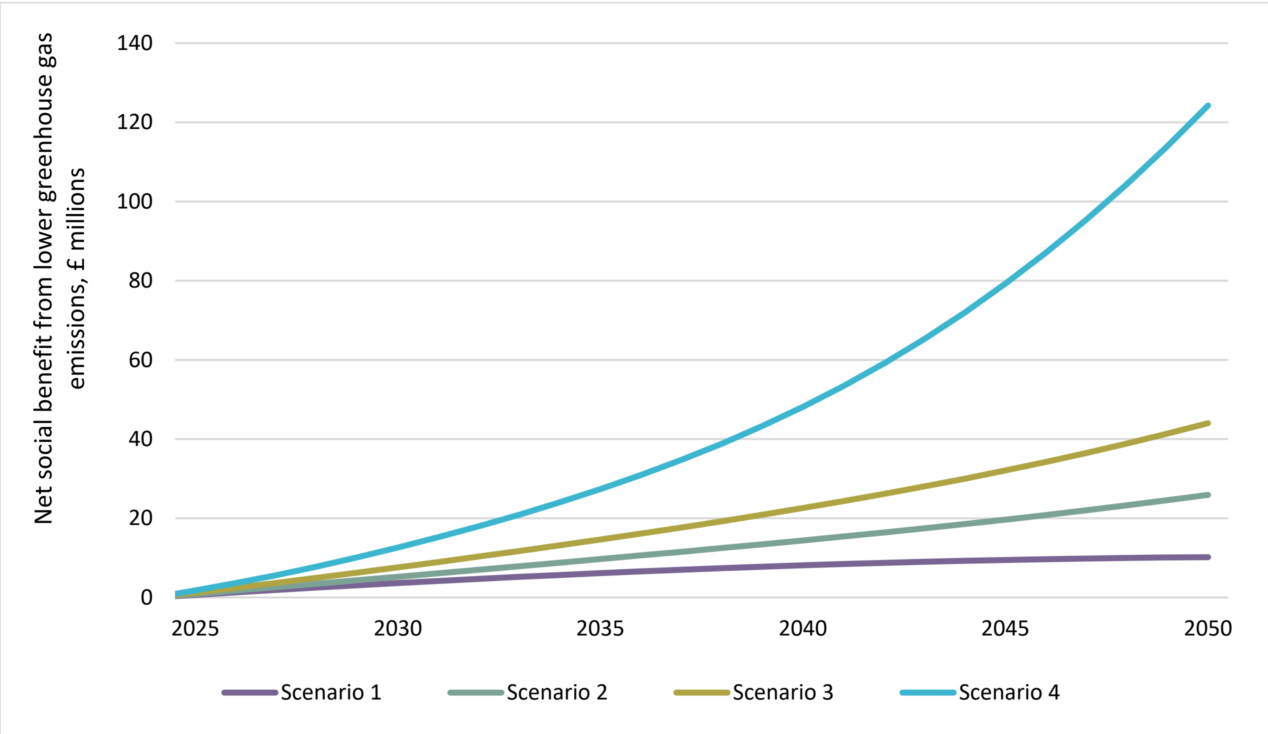

Figure 18: The cumulative environmental impact from reducing emission by using AAM and UAS across scenarios.

[44] TAG data book - GOV.UK

5.2 Scenario 1 – Low sector growth

Figure 19 and Figure 20 presents the cumulative revenues for AAM and UAS in scenario 1. The revenues are primarily driven by the entry into service year, as slower regulatory development means eVTOLs do not enter into service until 2034 so there is passenger market for AAM until the mid-2030s. In addition, in this scenario there is a general distrust from the public towards autonomous technologies due to safety and privacy concerns, this results in autonomous UAS entering operations late in the period, whilst autonomous AAM does not enter operation at all. This results in lower revenues when compared to the other scenarios. The majority (65%) of total UAS revenues are generated by commercial UAS contractors. Over half of the AAM revenues are from passenger transactions.

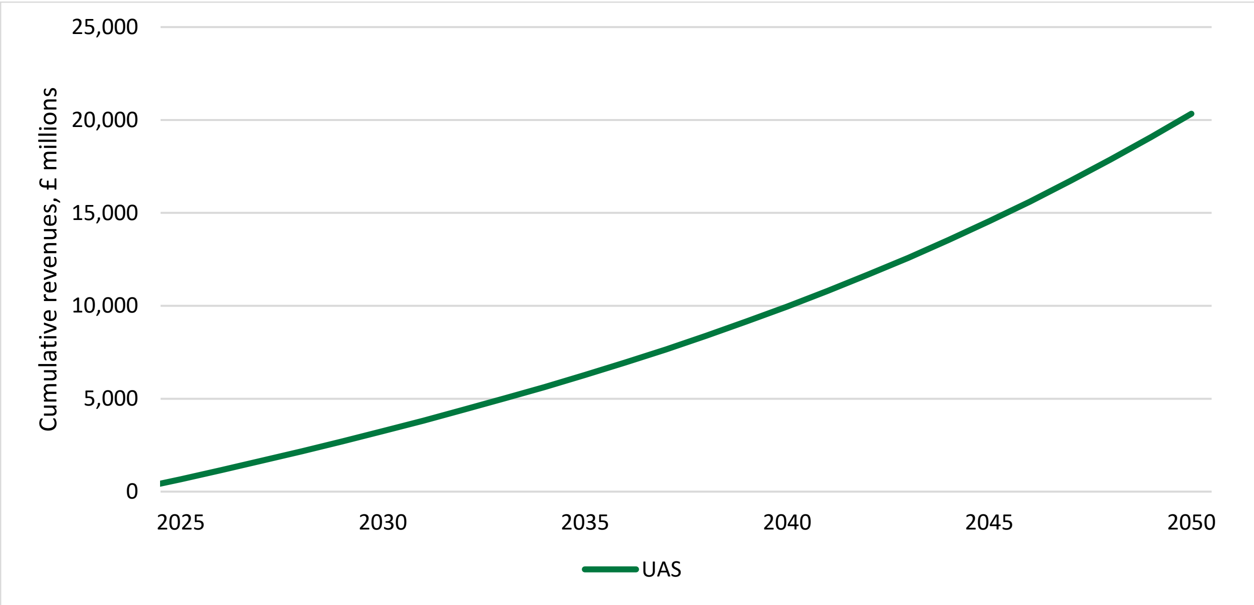

Figure 19: Cumulative UAS revenue in scenario 1 (low sector growth)

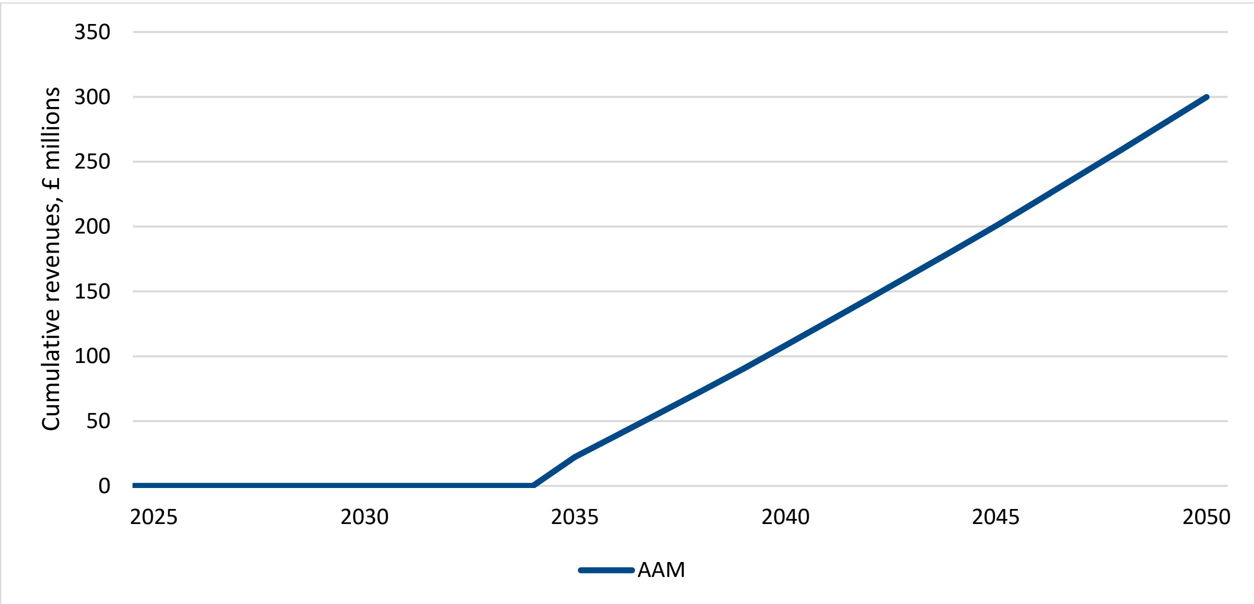

Figure 20: Cumulative AAM revenue in scenario 1 (low sector growth)

UAS and AAM could contribute £24 billion in GVA and 610,886 job-years to the UK economy by 2050 as shown in Figure 21 and Figure 22 respectively. These estimates represent gross economic activity through the creation of AAM infrastructure and expansion of UAS use into the use cases.

The GVA contribution is separated between direct impact (economic activity in the first round of suppliers), and indirect and induced impact (economic activity in the supply chain). In scenario 1 the indirect and induced impact is lower compared to other scenarios. The main driver of the low impact in scenario 1 is the heavy import reliance of the UK future flight sector, particularly in UAS, which results in a large amount of future flight spending leaking out of the UK economy. The high level of import reliance is driven by a relatively low skilled UK future flight sector, as well as unfavourable investment conditions for AAM and UAS in the UK.

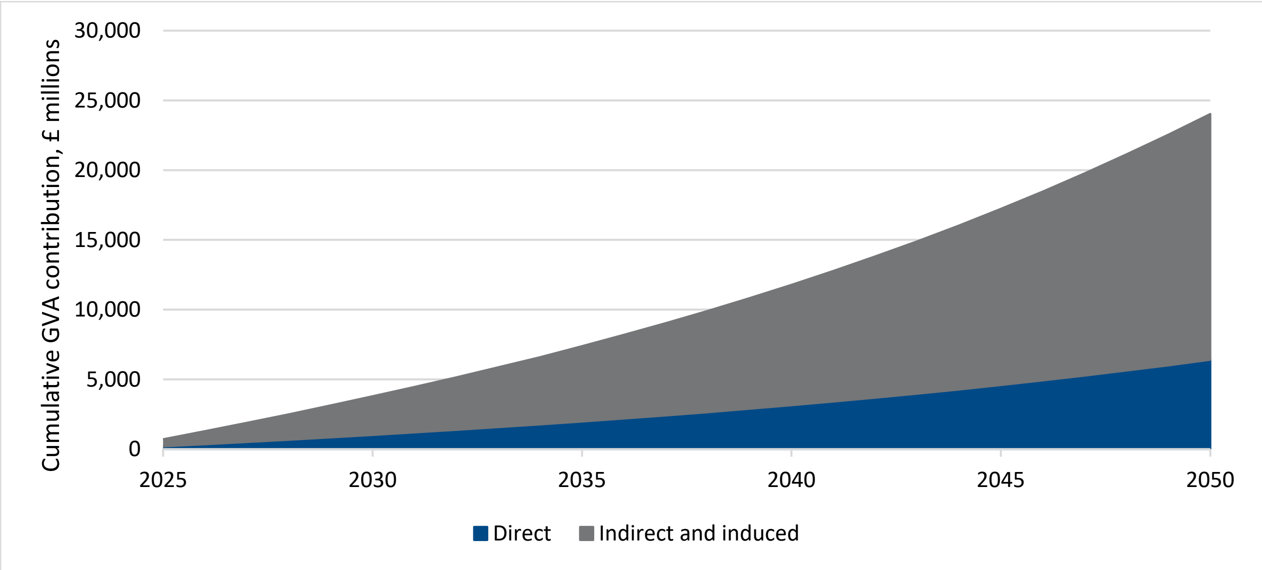

Figure 21: Cumulative GVA contribution in scenario 1 (low sector growth)

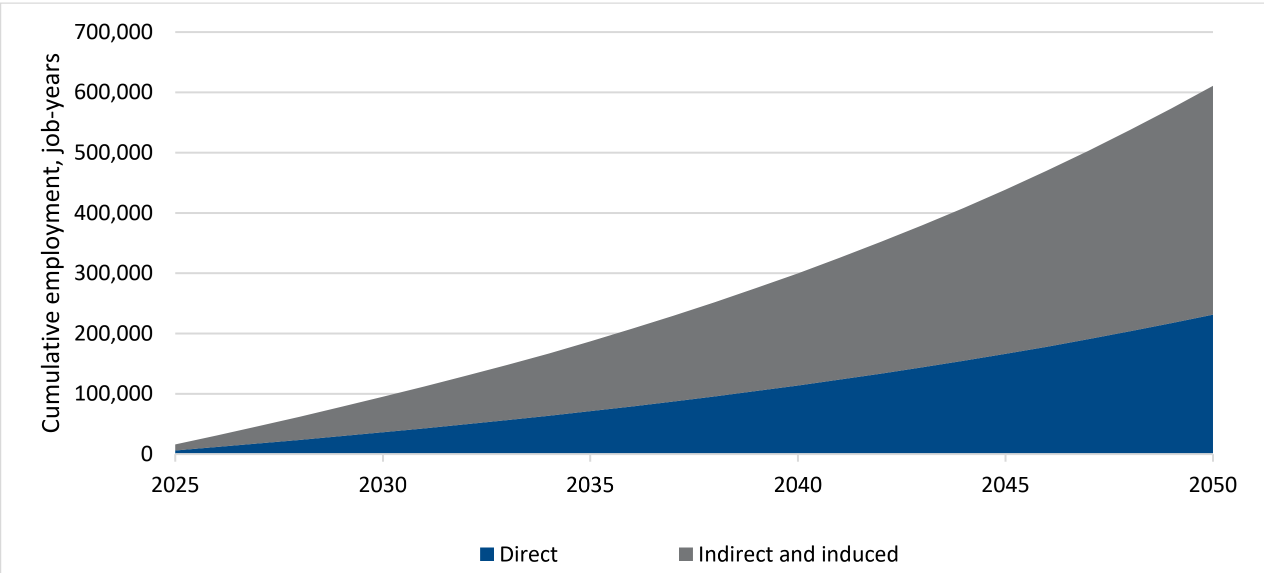

Figure 22: Cumulative job-years in scenario 1 (low sector growth)

5.3 Scenario 2 – Acceptance by business but not general public

Figure 23 and Figure 24 presents the cumulative revenue of UAS and AAM for scenario 2 respectively, where there is a positive perception from businesses for future flight but not from the general public. UAS is limited to being used for infrastructure inspections and emergency services support but not for public facing use cases such as UAS drone delivery due to privacy and safety concerns for the general public. This is also true to UAM and RAM, limiting the growth of this sector in scenario 2. Over 75% of UAS revenues are due to commercial revenues from businesses using UAS to provide their services. 55% of AAM revenue is from passenger ticket sales, this is due to lower infrastructure revenue in scenario 2 relative to the other scenarios.

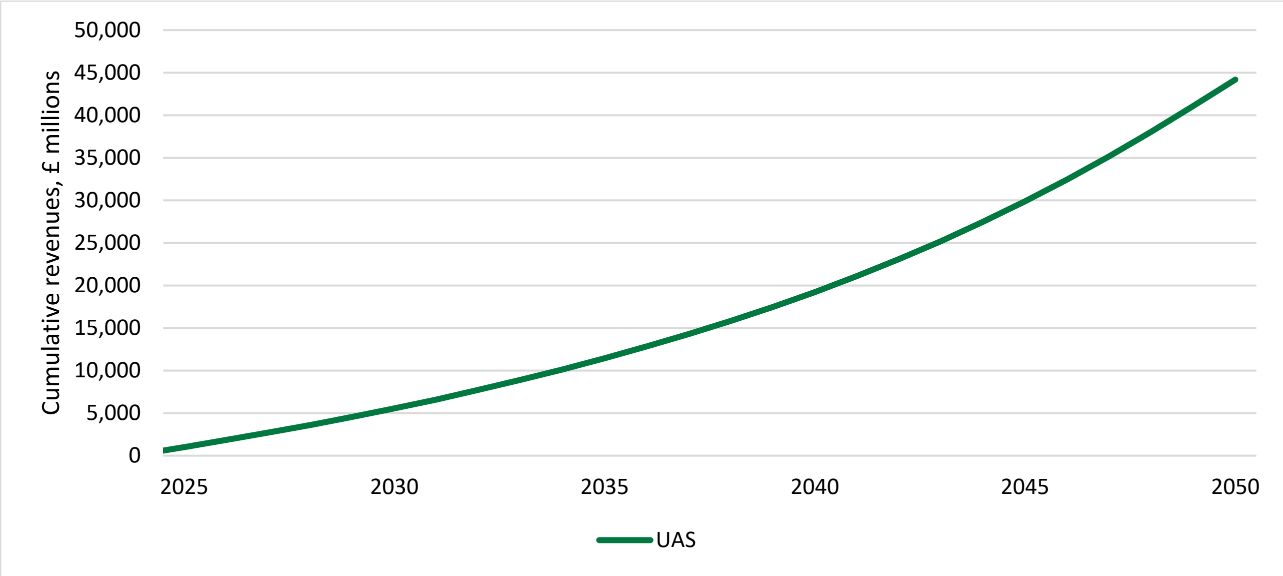

Figure 23: Cumulative UAS revenues for scenario 2 (acceptance by business but not general public)

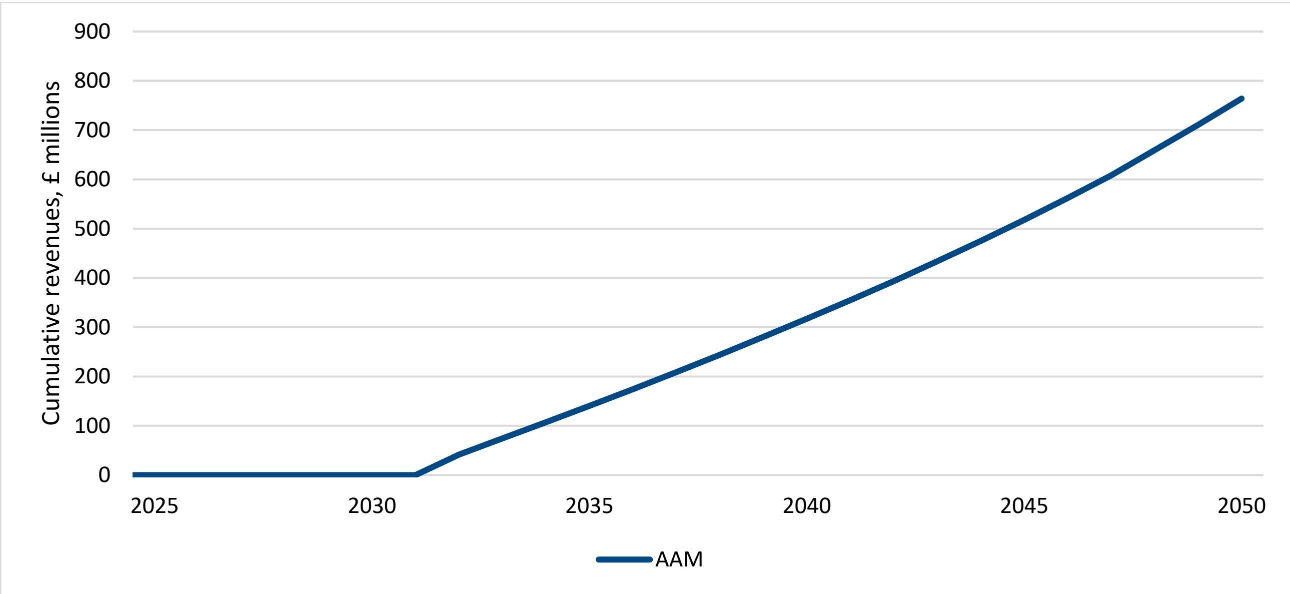

Figure 24: Cumulative AAM revenues for scenario 2 (acceptance by business but not general public)

Under scenario 2, UAS and AAM contributes £63 billion in GVA and 1.8 million job-years to the UK economy, this is shown in Figure 25 and Figure 26.

The principal driver of variation in this scenario is end user buy in with the perception of end users, business and passengers, being different. This results in demand for UAS commercial use cases growing at a faster rate than passenger facing use cases. From a policy perspective, policies relating to public relations and ensuring end user buy-in from all stakeholders will be necessary to drive the UK future flight market.

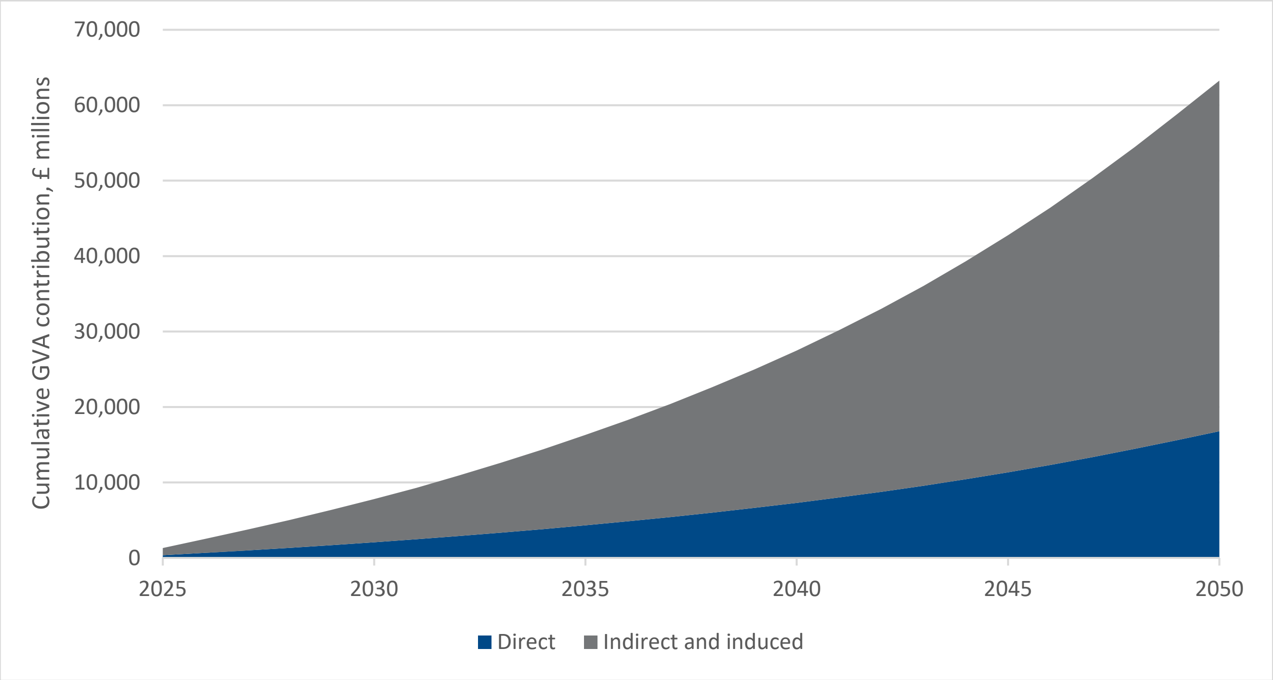

Figure 25: Cumulative GVA contribution for scenario 2 (acceptance by business but not general public)

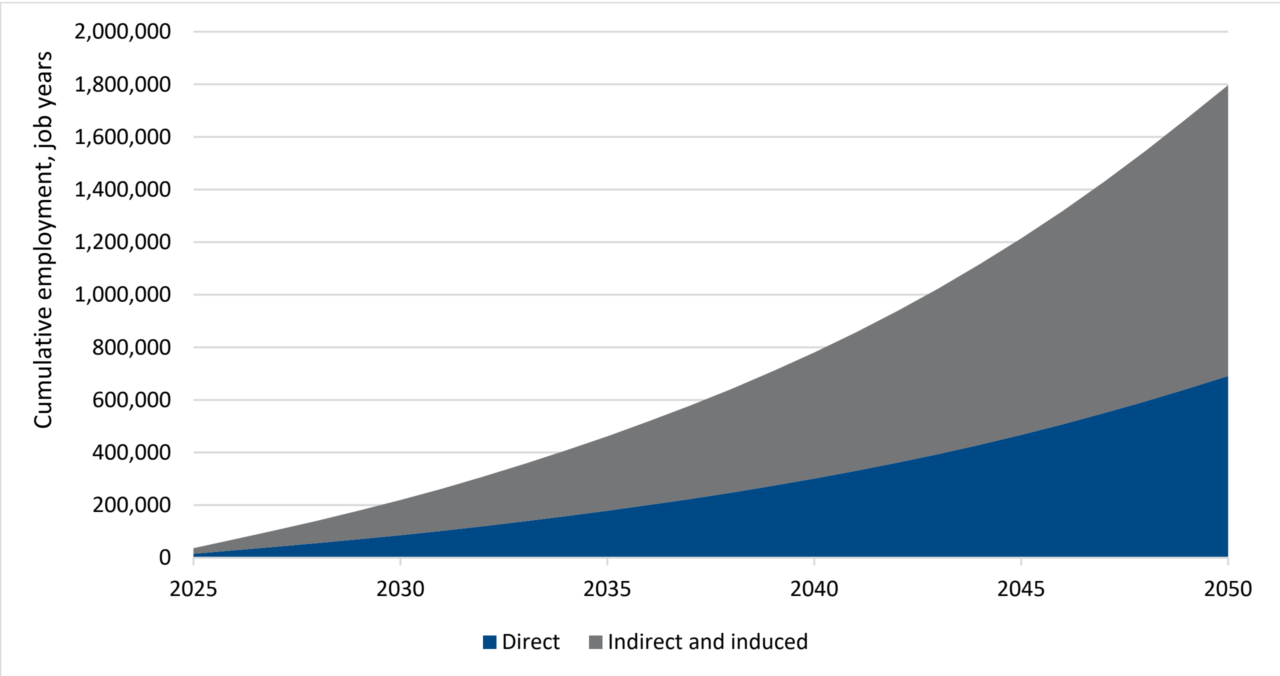

Figure 26: Cumulative job-years for scenario 2 (acceptance by business but not general public)

5.4 Scenario 3 – Technological breakthrough in AAM in the UK

In scenario 3, AAM market revenues are expected to reach £2.5 billion by 2050. UAS revenues reach £31.4 billion, which is lower than the UAS market activity seen in Scenario 2. The higher revenue for UAS is due to higher platform and commercial prices as there are expected to be lower levels of competition.

The technology breakthrough in AAM in the UK supports the establishment of a highly skilled AAM sector, which is less import dependent, as the market is nascent and does not yet have a monopoly. As the UK AAM establishes itself at the forefront of the global market, there is a likelihood that overseas AAM companies will relocate to take advantage of the UK labour market and technology. In addition, the higher skills and increased benefits from learning causes AAM manufacturing prices to fall leading to lower startup costs for AAM manufacturers.

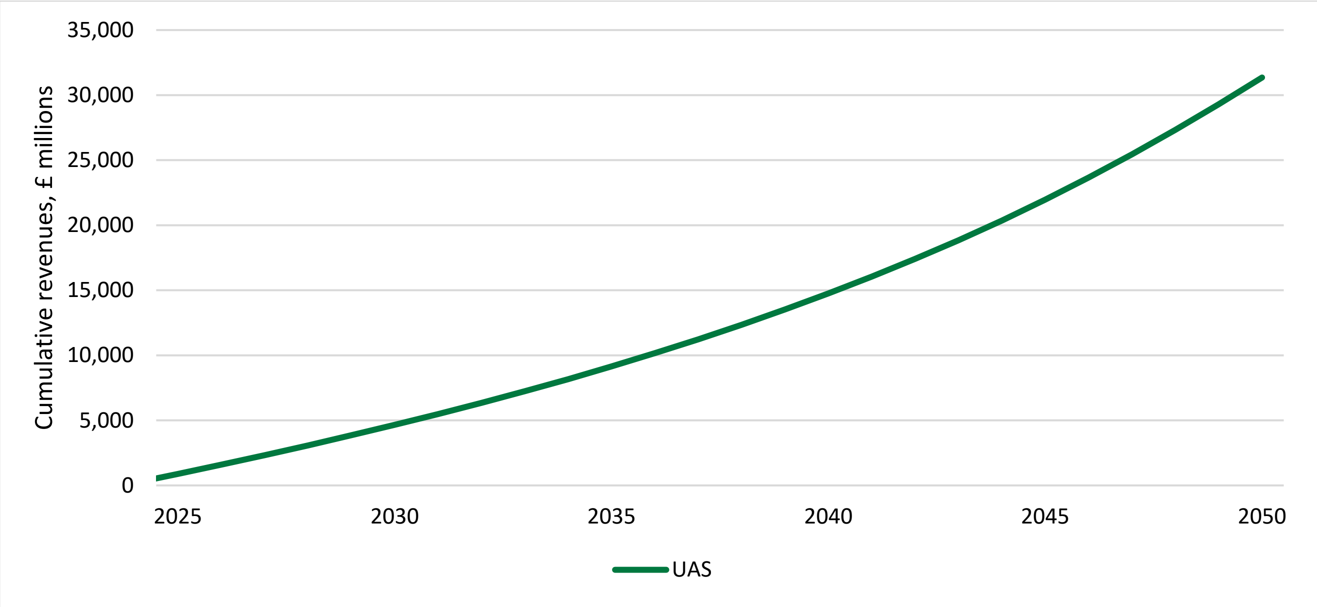

Figure 27: Cumulative revenue for the UAS market in scenario 3 (technology breakthrough in AAM)

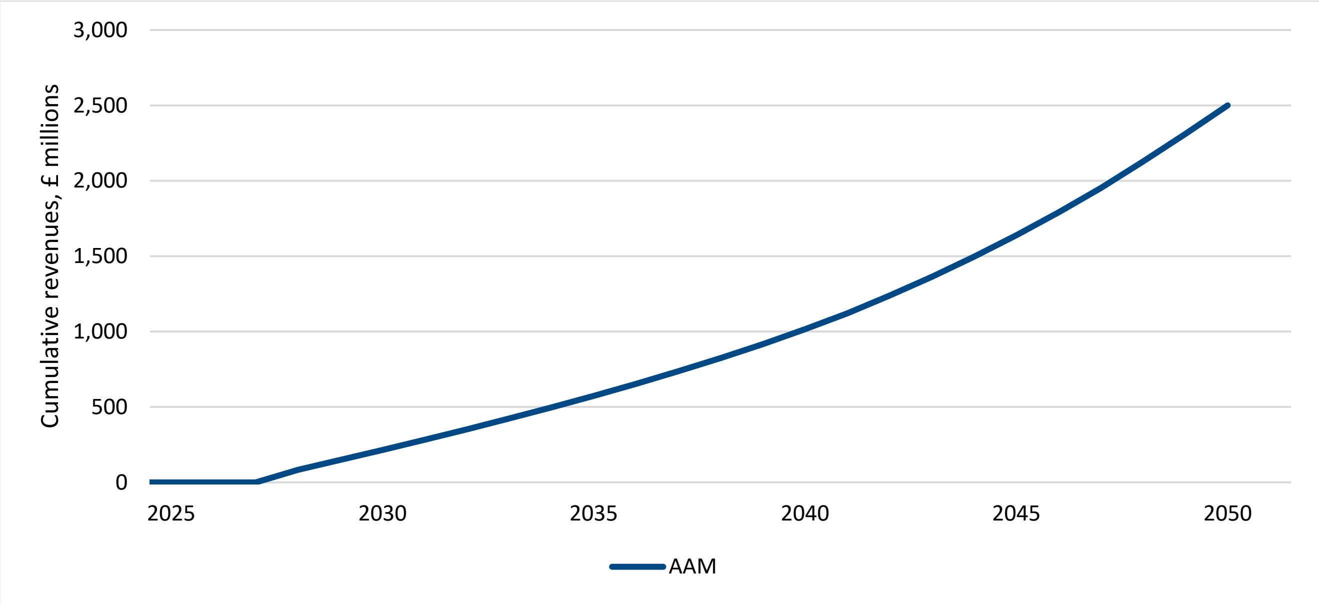

Figure 28: Cumulative revenues for the AAM market in scenario 3 (technology breakthrough in AAM)

Under scenario 3, UAS and AAM could contribute of £44.3 billion in GVA, and more than 1.3 million job-years to the UK economy, Figure 29 and Figure 30. These estimates are net additional to the UK economy.

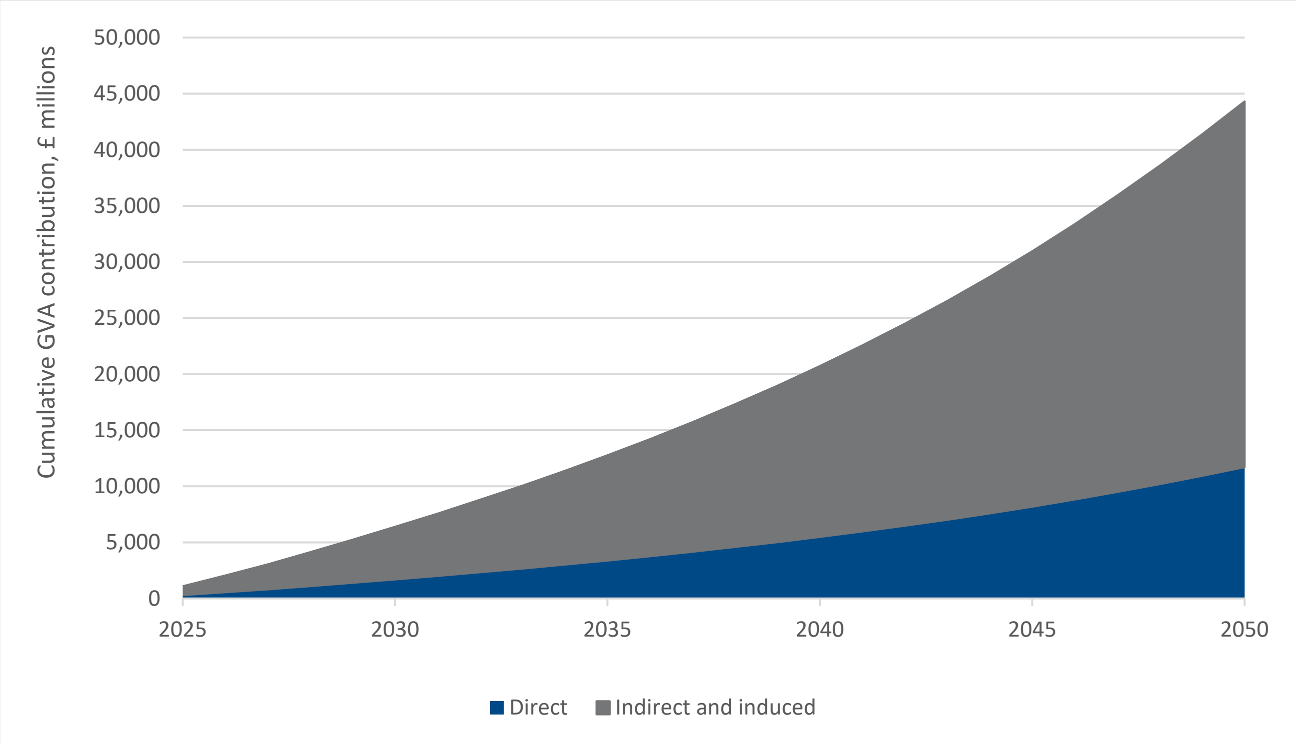

Figure 29: Cumulative GVA contribution in scenario 3 (technology breakthrough in AAM)

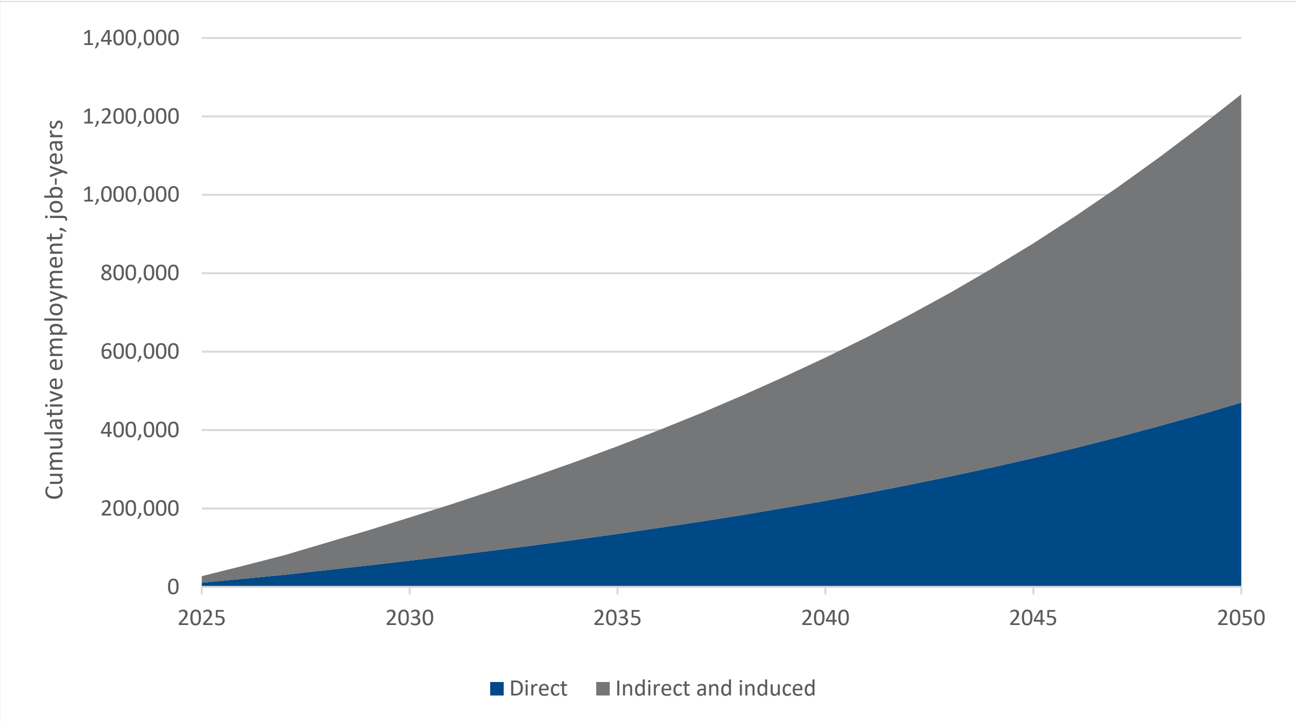

Figure 30 : Cumulative job years in scenario 3 (technology breakthrough in AAM)

5.5 Scenario 4 – High sector growth

Scenario 4 presents high revenues for both AAM and UAS and reflects an optimistic view of the UK future flight sector. The main drivers of revenue are the high levels of end user buy-in with strong acceptance for UAS and AAM in an integrated transport network, as well as an expansion of diverse use cases around the economy. The positive perceptions towards autonomous UAS and AAM, which represent higher revenue per unit than piloted platforms, lead to autonomous operations bringing in more GVA and job-years to the economy. 80% of the UAS market revenues are due to UAS commercial activities. AAM revenues are split between passenger revenues and vertiport revenues, with very little market revenue generated by vehicle manufacturing.

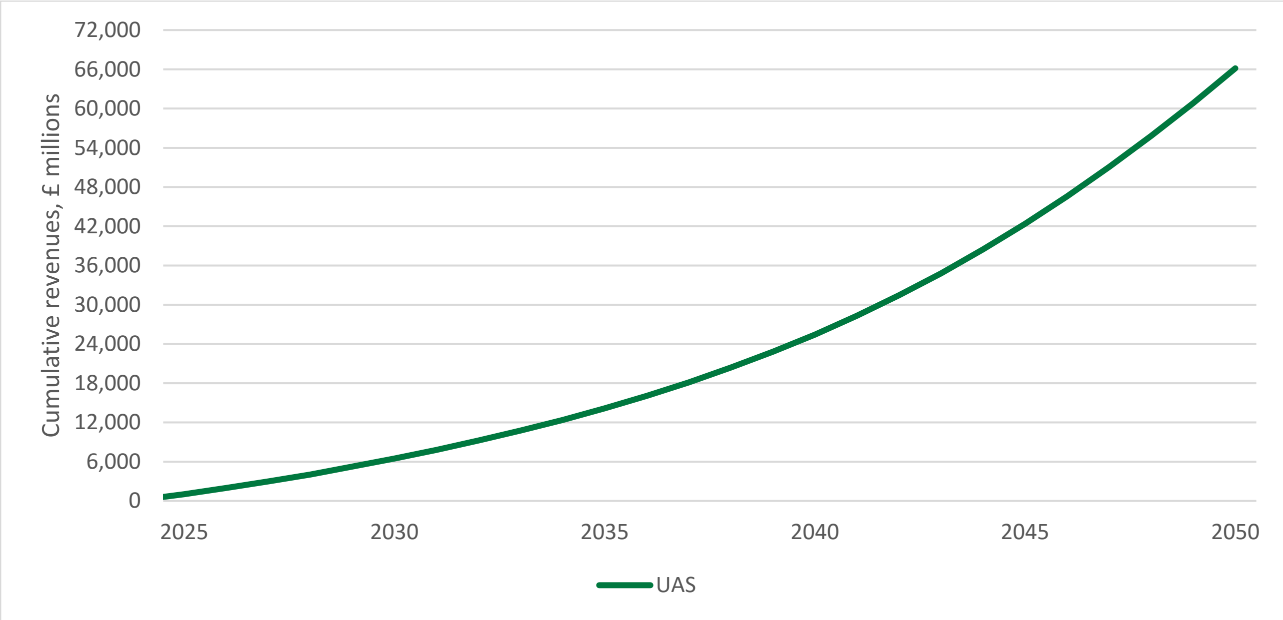

Figure 31: Cumulative UAS revenues for scenario 4 (high sector growth)

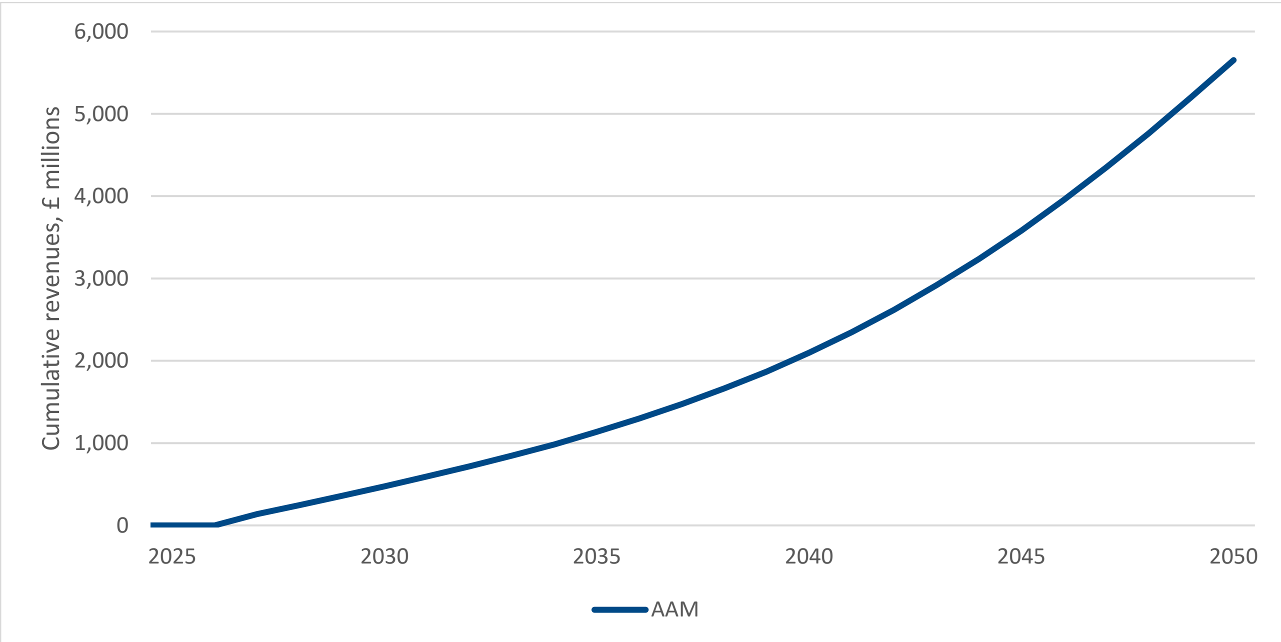

Figure 32: Cumulative AAM revenues for scenario 4 (high sector growth)

Under scenario 4, UAS and AAM generate expenditure in the UK economy through direct purchases and revenues, with a knock-on procurement in the supply chain and household spending from new wages. The value of these effects suggest the UAS and AAM markets could contribute £103 billion in GVA and 3 million job-years by 2050 (Figure 33 and Figure 34).

The economic impact of scenario 4 is driven largely by a lower proportion of imports to the future flight market. This is caused by high levels of demand and effective regulation establishing a favourable investment environment for overseas firms including relocation, this helps to establish a strong future flight manufacturing base in the UK which helps to retain economic activity.

Scenario 4 represents the upper bound of economic impact and revenues generated by the UK future of flight market by 2050. This is inclusive of vehicle revenues, infrastructure revenues, and commercial revenues.

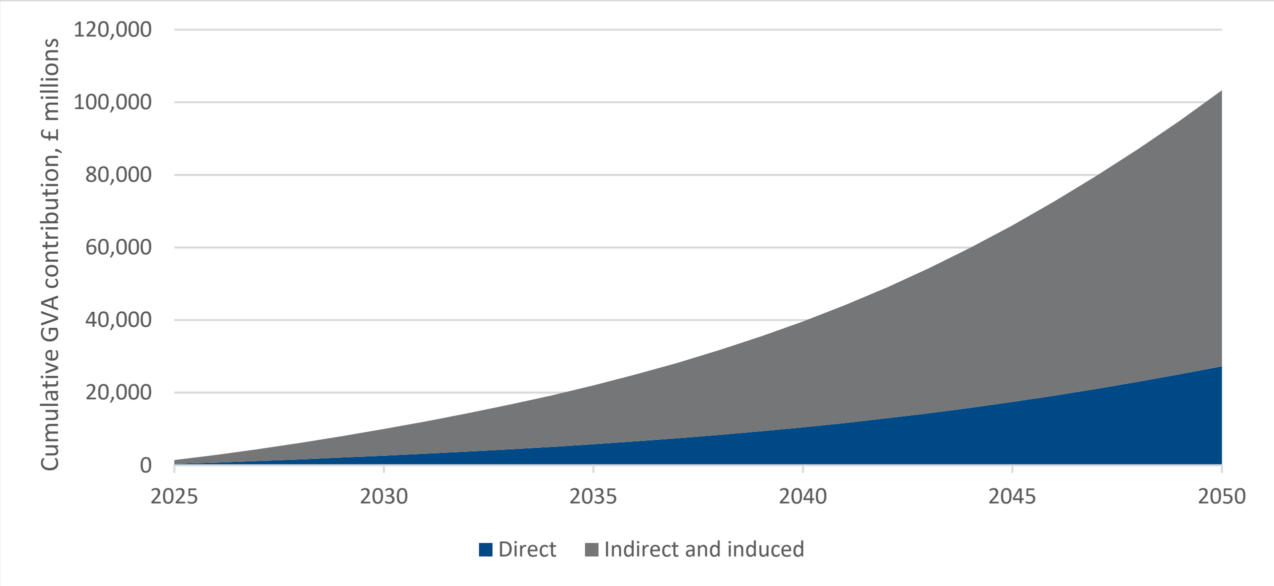

Figure 33: Cumulative GVA contribution for scenario 4 (high sector growth)

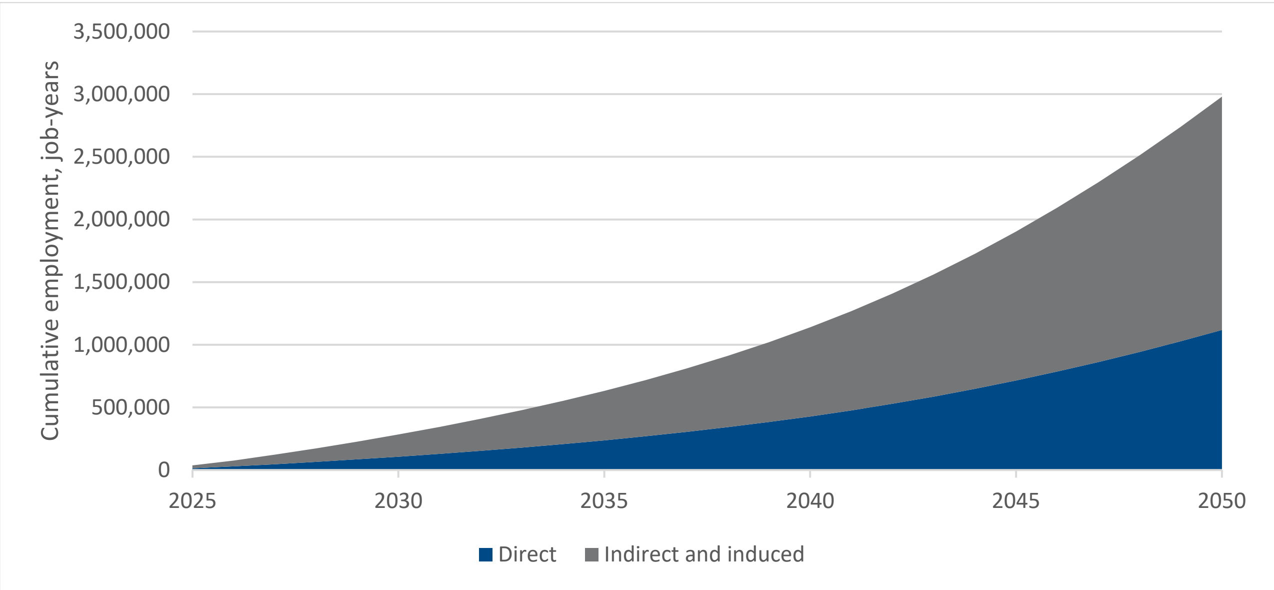

Figure 34: Cumulative job years for scenario 4 (high sector growth)

6 Conclusions

Building on the existing evidence base and policy, this project has developed four scenarios for future flight in the UK. They covered possible future states of the UAS and AAM sectors up until 2050 and quantified the social and economic impact these technologies may have on the UK. Engagement with DfT stakeholders and industry experts helped to shape the scenarios' focus and to translate qualitative assumptions about key drivers and barriers into quantified scenarios covering UAS and AAM adoption. The DfT intends to draw on this research to expand the scope of their Common Analytical Scenarios to include aviation.

Scenarios **1: Low market growth** and **4: High market growth** provide the lower and upper bounds to the estimated future market size and corresponding benefit to the UK. They provide insight into how the outcomes can be affected by the ambitions from businesses, consumers and government in developing a strong future flight market. In essence, these two scenarios are driven by factors endogenous to the UAS and AAM markets. Scenarios **2: Acceptance by business but not by the general public** and **3: Technology breakthrough in the AAM market** are influenced by exogenous factors that dampened or enhanced demand. They emphasise the effect public acceptance of UAS use and the evolution of battery technology to power AAM service capabilities have on outcomes.

Estimating the social and economic impact on the UK showed how each scenario was varied by aggregate UK supply chain impacts, passenger impacts and environmental impacts. The cumulative economic impact of UAS and AAM markets on the UK could be between £24 billion (Scenario 1) and £103 billion (Scenario 4) by 2050. These results are estimated as the gross impact on the UK economy. These scenarios represent the upper and lower bounds of the UK future flight market by 2050. The range between results is the result of varying uncertain drivers and barriers to capture a spectrum of potential impact in the UK.

In each scenario, the role of the UK government is to facilitate growth without the need for large scale unmatched funding. Using the scenarios, this report shows that future growth in these markets relies heavily on the public perceptions of the new technologies being developed, the speed of technological readiness for regulations and required infrastructure, and the relative strength of these markets in the UK compared to the global markets. Therefore, this report recommends that policy and regulation for future flight continues to work with industry to focus on:

- Enabling early use of the technologies, and
- Public relations to support end user use,
- Development of associated manufacturing and operational skills,
- Facilitating the growth of the required manufacturing base,

6.1 Further research

Whilst the scenarios have been built on stakeholder insights and existing market analysis, the future of the UAS and AAM markets remain highly uncertain. There are opportunities for further investigation into the substitution away from current modes of activity towards the use cases analysed in this report. This is because rates of adoption for each use case drive a significant portion of the future market potential, for example greater evidence of the rate at which taxi users might adopt AAM services. This will be necessary to create robust estimates of additionality for future flight.

Whilst the future airspace will be occupied by a range of aircraft types, this analysis focused on the potential future UAS and AAM markets to the exclusion of other aircraft. Further research to inform the future composition and regulation of UK airspace would add a greater level of clarity to the future flight scenarios presented in this report.

Intellectual property (IP) rights are vital in emerging sectors as a means of protecting firms who are engaging in technological innovation. Such rights are likely to be crucial in the future flight sector, however, limited data on property rights makes the benefit of IP protection difficult to quantity within the scope of this research. Further work should be undertaken to evaluate the benefit to firms of IP protection. This research could be incorporated within future impact evaluations of Future Flight Challenge, Aerospace Technology Institute or National Aerospace Technology Exploitation Programme (NATEP).

Further research and coordination should be carried out to explore the impact of electric aviation (UAS and eVTOLs) on the UK's critical mineral supply chain. A large increase in electric UAS platforms will place additional pressure on the UK's lithium supply chain, as well as the UK's lithium recycling capability. The UK government has recently published the new critical minerals strategy which indicates the need to secure the supply chains and disposal of lithium, cobalt, and graphite for electric vehicle batteries.[45] The existing research into UK critical minerals focuses on the automotive industry with less emphasis on aerospace. The impact of future flight on the UK's critical mineral supply chain and recycling capability must be researched further.

A final area for further research relates to impacts from UAS noise, whilst data exists for the noise impact of aviation this data is likely not applicable to drone noise due to differences in sound characteristics, volume and altitude. Therefore, further work should be undertaken to understand the impact of drone noise prior to integration with other transport modes. This information is also key to frame public relations by understanding the impact drones may have on the public.

45 UK critical minerals strategy

Glossary

Table 7: Glossary of key terms

Term	Definition
Advanced Air Mobility (AAM)	Next generation of air transport systems intended for both Urban Air Mobility (UAM) and Regional Air Mobility (RAM) solutions. (e.g. eVTOL, eCTOL, eSTOL).
Assumption	A statement which is accepted as 'true' to help define a system.
Autonomous	Platform performs operations without the need of a pilot.
BVLOS	Operation of a remotely piloted platform beyond the visual line of sight of the pilot.
CTOL	Conventional take-off and landing aircraft. This is referred to as an eCTOL when electrified.
Future of Flight ecosystem	Stakeholders involved in the Future of Flight sector including industry, government, academia and regulators.
Parameter	A numeric or measurable value that can help define a system (e.g. number of UAS by 2050).
Regional Air Mobility (RAM)	Point to point transport of passengers and cargo over longer distances (up to 1000km), including transport into rural areas.
Scenario	Alternative description of how AAM and UAS ecosystem may develop in the future.
STOL	Short take-off and landing aircraft which can take-off and land over a shorter distance than a conventional aircraft. Also referred to as an eSTOL when electrified.
Uncertainty	A statement that implies more than one outcome is possible (e.g. future GDP growth).
Uncrewed Air System (UAS)	Aircraft and its associated elements which are operated with no pilot on board (e.g. drones).
Urban Air Mobility (UAM)	Point to point transport of passengers and cargo around cities and between close together cities.
Use case	A defined set of actions or activities which collectively demonstrate a solution that meets the needs of a user.
VTOL	Vertical take-off and landing, in which the aircraft takes-off and lands through hovering. Also referred to as an eVTOL when electrified.

Annex A - Futures workshop outputs

A.1.1 Workshop overview

To develop a set of robust future flight scenarios, it was important to understand the key drivers and barriers that may lead to significant change to the ecosystem. To achieve this, Frazer-Nash facilitated a workshop with government, industry and academia with the following aims:

- Identify the drivers and barriers that could impact the future of the sector.
- Agree on the key medium-term and long-term uncertainties.
- Define a set of scenarios.
- Identify the UK strengths and weaknesses and compare to other countries.

Workshop attendees included representatives from the CAA, DfT, UKRI, British Standards Institute (BSI), Bath University and ARPAS UK, allowing for a range of different perspectives of the ecosystem to be collated.

The workshop activities were based on the futures toolkit guidance on scenario creation, these are shown in Figure 35:

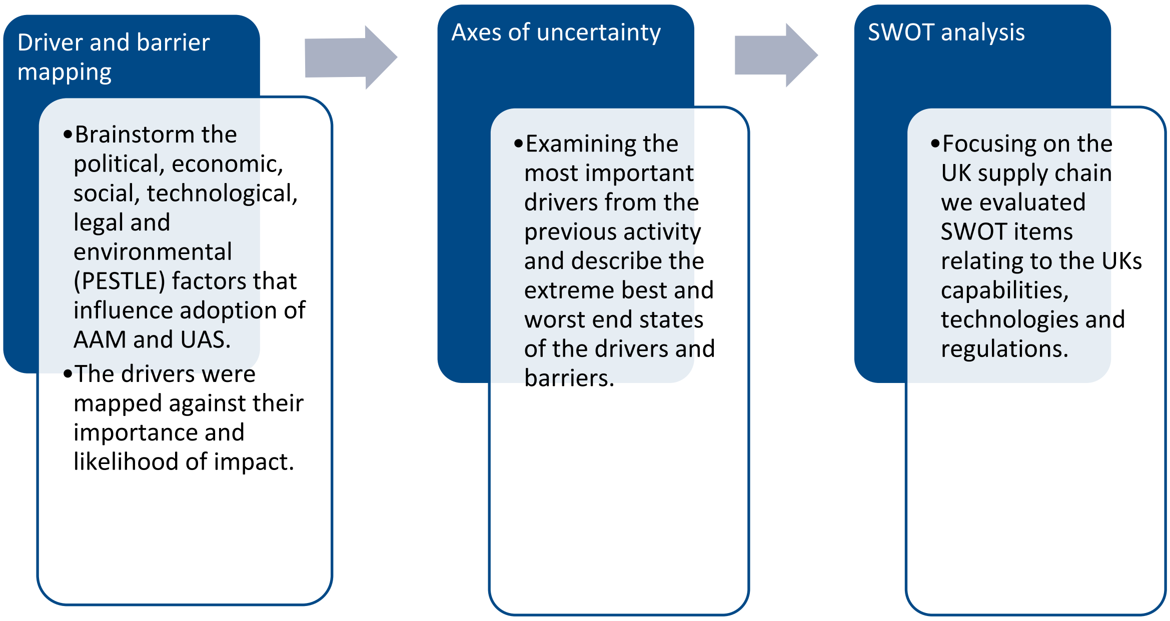

Figure 35: Futures workshop activities.

A.1.2 Driver and barrier mapping

The first workshop activity was the identification of drivers and barriers that may affect to the adoption of AAM and UAS in the UK. Attendees brainstormed the political, economic, social, technological, legal and environmental (PESTLE) factors that may contribute to the use of the technologies. The following definitions were adopted for drivers and barriers:

- **Driver:** A factor that can contribute to accelerating adoption of AAM and UAS in the UK.
- **Barrier:** A factor that can present an obstacle or hindrance to the adoption of AAM and UAS in the UK.

The output of this activity is shown in Table 8.

Table 8: Driver and barrier PESTLE analysis

	Drivers (positive contributors to change)	Barriers (negative contributors to change)

Political	• Clear communication of the benefits of future flight between government and industry (particularly local government).
	• Integration between future transport and education to improve public buy-in.
	• Education of local authorities on the future flight sector.
	• Political will – to enable, fund, and support.
	• Widening participation of policymakers in discussions around topic of future flight – currently mostly limited to specialist/focus groups.
	• Future policy on integration/integrated plans on different transport sectors, including road, rail, aviation and maritime.
	• Engagement with local airfields around how to integrate with future airspace/policy plans.
	• Increased alignment with European Union Aviation Safety Agency (EASA) regulation, easing workload on the CAA.
	• International regulatory agreements e.g. EASA, Federal Aviation Authority (FAA), facilitating the growth of a harmonised international approach to future flight regulatory development.
	• International relations, facilitating agreements such as above and collaboration/technology sharing.
	• Public message and education on future flight, to affect public opinion.
	• Government strategy for:
	  ○ Innovation
	  ○ Industry
	  ○ Defence
	  ○ Transport
	  ○ Jet Zero
	  ○ Aviation
	• Government UAM/AAM strategy, what will the network look like for the UK.
	• Intermodal strategy: how will future UAS/AAM networks be linked to other forms of transport.
		• Local planning laws conflict between vertiports and other uses.
		• Level of devolution of authority to local levels and its impact on development of future flight.
		• Change of government, resulting in change in stance on future flight.
		• Defence vs Civil UAS investment.
		• Uncertainty in responsibility/source for funding infrastructure (central government, regional government, private sector…).

Economic	• National economic landscape (growth, stagnation, recession). • GDP and jobs growth. • Export opportunities for UK-based vehicle manufacturers and service providers. • Supply and demand of future skills relevant to AAM and UAS development. • International competition driving R&D developments and funding. • Relative time and cost of UAS and AAM relative to other modes of transport. • Integration of AAM services into the wider transportation network, complementing existing networks. • Buy-in from industry decision makers on UAS usage, potentially supported by policy e.g. mandating UAS for work at height where possible. • Diversity of use cases, diversifying and growing the sector. • Trends in urbanisation and urban congestion, use of cars, affecting the demand of time-saving travel modes such as AAM. • Private investment from venture capital.	• Lack of availability of data for cost, benefit, and environmental impact modelling. • Long term uncertainty of research and development (R&D) funding. • Fiscal trade-offs between public investment in AAM and UAS and other public spending priorities. • National economic environment being unfavourable for AAM and UAS investors (e.g. interest rates, access to credit). • Speed of scale up of operations, affecting the economic viability of AAM operations.
Social	• Education of wider public on the future flight sector to allow more informed opinions and decision making. • Education for industry on the opportunities (from a non-aviation perspective., with regards to UAS in particular). • Population aging and its impact on demand (e.g. increased requirement for at-home medical delivery services). • Demand for AAM/UAS services. • Demand for better rural and periphery connectivity, as well as from hospitals & other institutions. • Strategic emergency response to incidents starting. • Academia pushing future flight developments. • Population increases and its impact on demand. • Urbanisation of population and its impact on demand. • Time savings of AAM/UAS relative to other services, and its impact on demand. • Effect on mobility of the growing UK workforce. • Workforce. Skills & training in a high-tech sector.	• The public's perceptions of the safety and security impacts of UAS/AAM. • The public's perceptions of privacy impact from increased UAS use. • The public's perceptions of autonomy (safety, usability, ethical perceptions). • Conflict with airspace users (e.g. non-commercial operations). • Gender and social imbalances, particularly access to industry. • Vertiport security considerations, compared to commercial air traffic passenger security procedures. • Demographics in rural areas limiting adoption of rural air mobility. • 'Dirty' energy public perception, referring to concerns that EVs are not always charged using energy generated in a sustainable manner. • Safety 'incidents' creating a negative perception.

Technological	• Developments of future airspace management technologies to accommodate AAM and UAS technologies. • Digital infrastructure being able to accommodate AAM and UAS, including Unified Traffic Management and widespread electronic conspicuity adoption. • Data transfer and sharing facilitating development of an integrated flight information system. • Digital trust: connecting new technology to existing secure infrastructure. • Development of battery technology and its impact on scalability of AAM. • Manufacturing expertise and its impact on UK-based companies. • Standards for interoperability and supply chain integration. • Transition of the sector from technology led to demand driven. • Platform performance including tests and trials. • Convergence of OEMs & supply chain resulting in larger, more focussed future flight sector. • Energy production strategy to accommodate sustainable power grid capable of meeting increased demand from EVs. • Use of existing infrastructure for UAS/AAM, reducing infrastructure development needs and costs.	• Low amount of user-friendly dissemination of technical performance data, needed to improve communication with decision makers. • Uncertainty surrounding future autonomy capability. • Electric vehicle (EV) charging capacity not ready to meet increased demand. • Uncertainty in physical infrastructure requirements and developments. • Non-travel time associated with AAM (e.g. vertiport security). • Cyber security concerns. • Other transport developments affecting the demand and views on AAM/UAS.
Legal	• Development of manufacturing regulations to improve the ease of doing business in the UK. • Regulation of private drone ownership (i.e. owned by individuals). • Public access and right to airspace and impact on uptake of UAS. • Insurance and liability frameworks for autonomous systems. • Development of digital flight rules facilitating AAM and UAS adoption. • Development of air traffic regulations to enable AAM and UAS in an integrated airspace.	• Differences around target safety levels (accident rate per flight hour) of eVTOLs (EASA Commercial Aviation 10^{-9} vs FAA small aircraft & helicopter 10^{-7}), and potential difficulties achieving a 10^{-9} level. • Future international regulation (e.g. EU) affecting UK regulatory decisions. • Speed/proactiveness of regulatory landscape to new developments. • Uncertainty around regulatory framework for autonomy/AI.

Environmental	• Decarbonisation of power sources for EV charging. • Approach to recycling (e.g. battery technology). • Congestion/negative impacts of existing modes of transport affecting UAS/AAM demand and uptake.	• Difficulty in collecting significant amounts of operational data relating to noise pollution. • Conservation areas at risk from noise and light pollution. • Land use concerns for vertiports (planning and regulation). • Environmental conditions/weather, impact on UAS/AAM. • Noise pollution from UAS/AAM especially in residential areas and its impact on public opinion and regulation.

The drivers and barriers were each mapped on a set of axes with four quadrants, in accordance with their importance and level of certainty surrounding their future state and development. The exercise was carried out in three separate groups at the workshop (for ease of facilitation), which generated three separate sets of mappings, as shown in Figure 36, Figure 37 and Figure 38 below. It is important to note that the axes are relative, in terms of some factors being less important than others, as this does not mean that the factor is not important at all. The drivers and barriers (each identified at the beginning of the box with either a ’D’ or a ’B’) are colour coded to their PESTLE category as shown in the key. The drivers and barriers deemed as most important and less certain (top right of the matrix) were carried forward to create the axes of uncertainty.

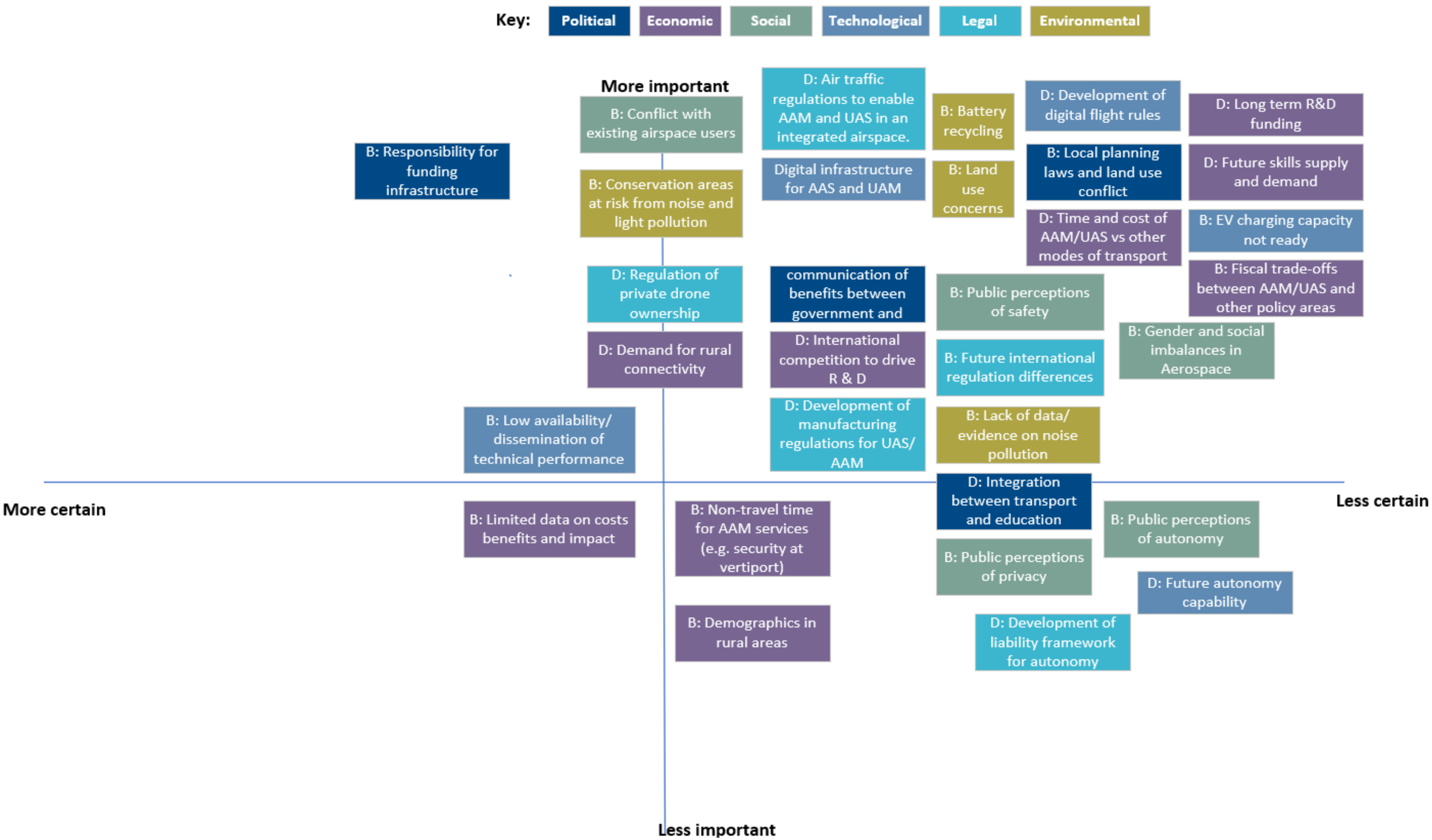

Figure 36: PESTLE outputs for workshop group 1.

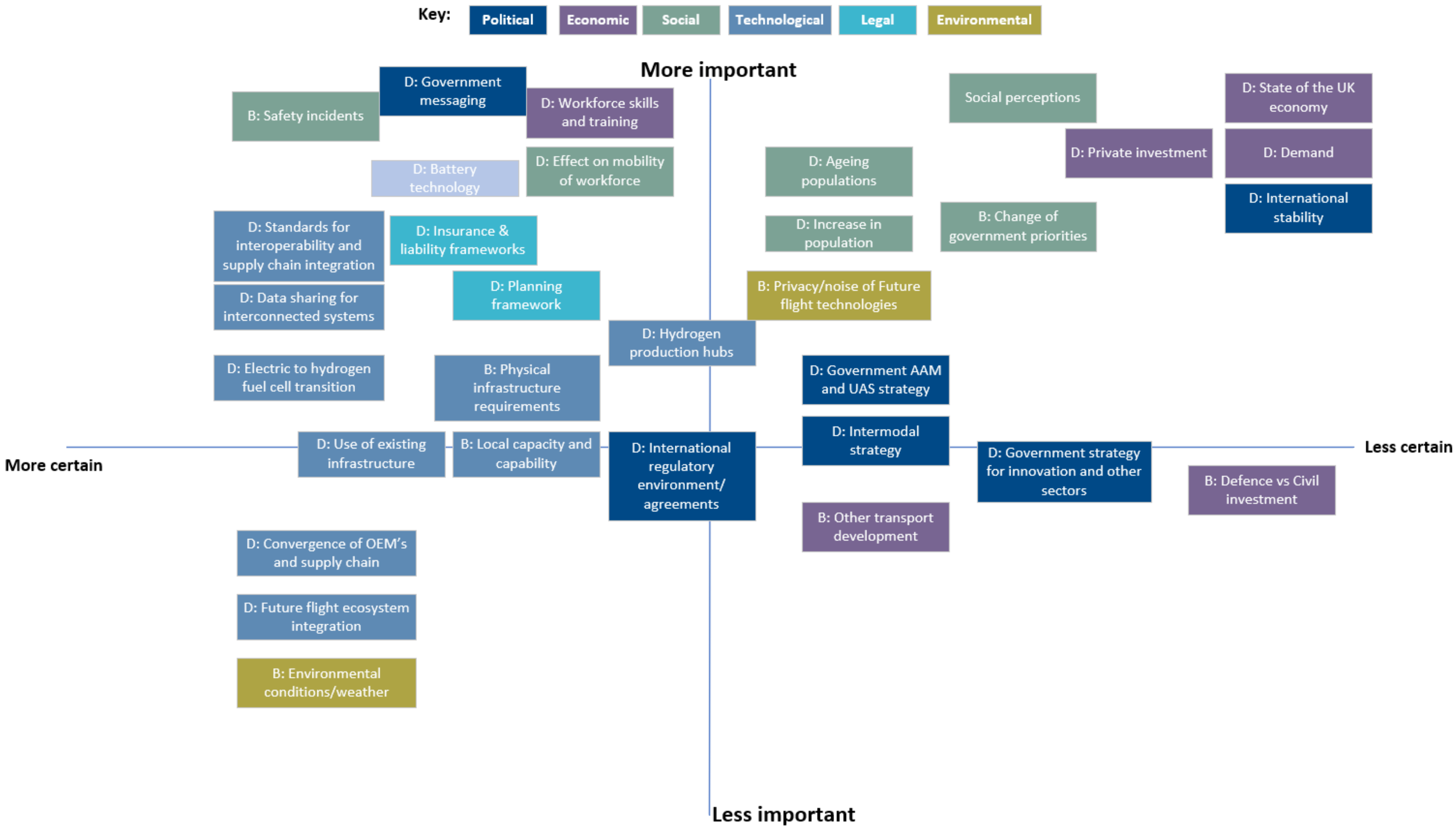

Figure 37: PESTLE outputs for workshop group 2.

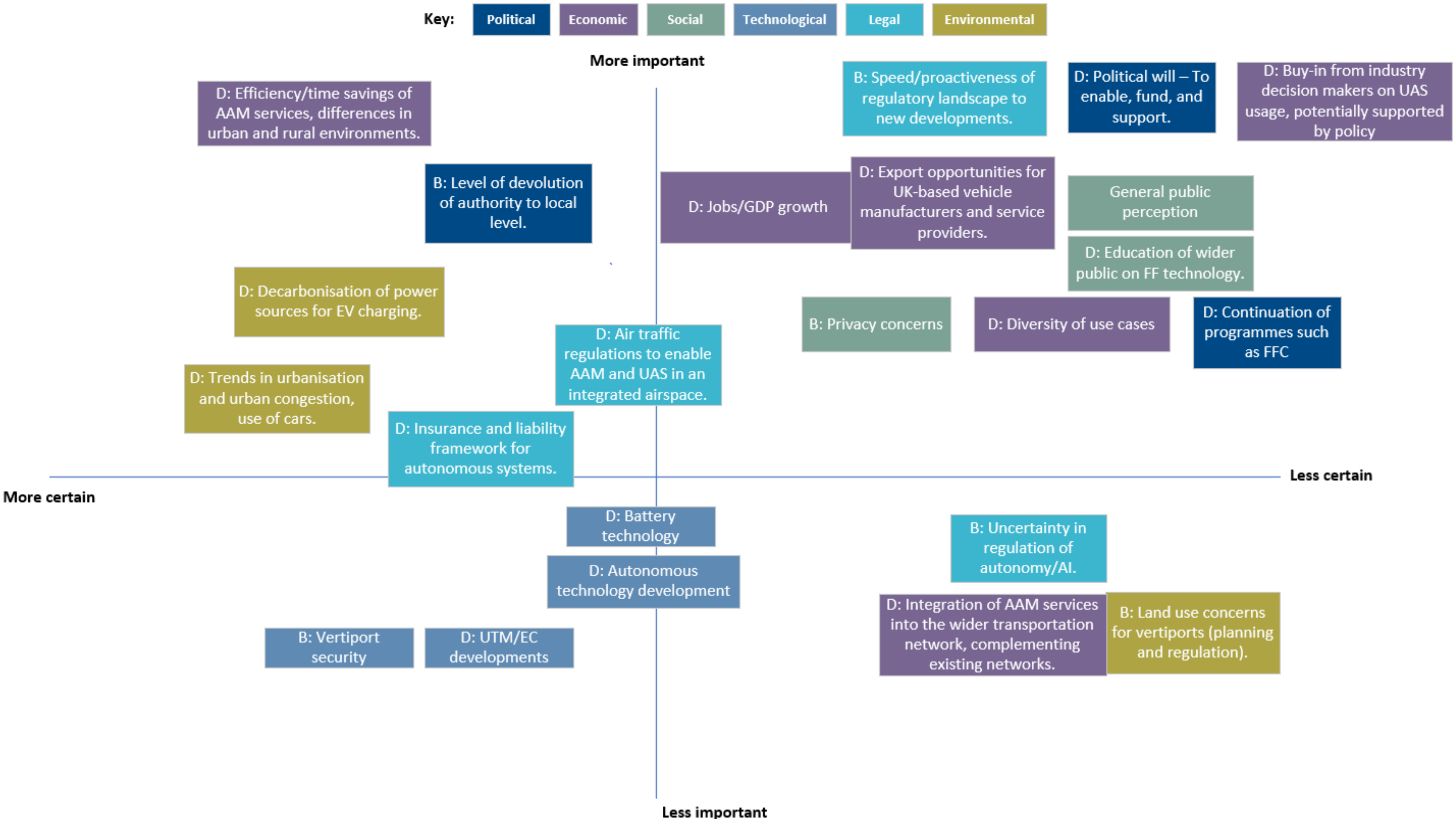

Figure 38: PESTLE outputs for workshop group 3.

A.1.3 SWOT analysis

The final workshop activity was a brainstorming exercise covering the strengths, weaknesses, opportunities, and threats (SWOT) for the UK AAM and UAS ecosystem including industry, supply chain, regulators and government. The outputs of this analysis were used to provide detail to the scenario narratives, alongside the drivers and barriers discussed in previous sections. The output of this activity is shown in Table 9 below.

Table 9: SWOT analysis

Strengths	Weaknesses
UK pedigree for innovation in aerospace, facilitating support for the sector. Focus on social acceptance through surveys and public dialogues. Government funding provided through future flight Challenge and Aerospace Technology Institute, creating a meaningful ecosystem. Integrated future flight ecosystem around a single focus. Information sharing across the future flight ecosystem. Diversification from traditional aerospace companies. Strong service industry. Industry invited to contribute to strategy. High standard of safety and regulation.	Commitment to funding post 2030 is unclear following the end of the Future Flight Challenge. Lack of/difficulty of utilisation of existing national infrastructure for AAM and UAS. Capture of wider aerospace ecosystem. Manufacturing at scale, scale of UAS companies. Big milestones linked to public relations. Exploitation of new future flight technologies past trial stages. Large infrastructure investments and projects can be difficult. Availability of raw materials (e.g. EVs/chips).
Opportunities	**Threats**
New framework for non-aviation drones (e.g. site monitoring), increasing worker safety. Strategy alignment with other policy areas. Exports of artificial intelligence and autonomy expertise. Communication of AAM and UAS costs, benefits, and environmental impacts. Green jobs and future flight skills. Leverage strong future flight ecosystem that facilitates communications between key stakeholders to make the UK a future flight hub. Remote areas (such as islands) to develop and trial new services. Strategy to involve local government at all levels.	80% of consumer UAS market is controlled by one overseas supplier. Governmental/policy change. Competition from countries with “lighter regulations” - difficult to run tests/trials in UK compared to certain countries. Competition from non-UK future flight funding Lack of return on investment. FFC concluding, unclear on continuation. Lack of significant development in AAM infrastructure.

Annex B - Scenario narratives

B.1.1 Scenario 1 – Low sector growth

The low supply-side growth scenario reflects a situation in which the UK does not view the future flight sector as a priority and is not attempting to be a global leader in the global future flight ecosystem. In this alternative future, the UK public and private sectors do not collaborate to develop a strategy to invest and direct the development of technologies and the required infrastructure for a functioning future flight ecosystem. This lack of coordination and direction also results in a reduced amount and effectiveness of private investment, with funds being allocated inefficiently. In addition, the lack of drive from the government has resulted in regulators being reactive rather than proactive with delayed regulatory developments for both UAS and AAM, which combined with the lack of strategic direction leaves their adoption limited and sporadic. The state of the uncertainties in this scenario is outlined in Table 10.

Table 10: Uncertainties relating to scenario 1.

Uncertainty	End state in 2050
Long term R&D funding	There is no funding for AAM and UAS in the UK with the public and private sectors prioritising other advanced technologies.
Physical infrastructure readiness	Physical infrastructure cannot meet demand and hinders further developments.
Future skills supply and demand	The demand for skilled workforce in the sector is low, and the general low interest also results in low supply, as few choose to specialise in the sector.
Local planning laws	There is lack of consistency between different local communities, and general indifference or opposition to construction of new future flight infrastructure.
Future airspace management	Future airspace plans do not account for nor facilitate widespread AAM and UAS use.
End users buy-in (i.e. demand for AAM and UAS)	Low buy in from users (including the public and businesses) resulting in limited incentives for investment.
Political will	Public and private sectors are not willing to invest in future flight R&D or infrastructure.
Diversity of use cases	Use cases remain very limited, due to demand and/or regulations.
Public/social acceptance	The sector is viewed with indifference or unease/uncertainty, largely due its overall lack of impact as a result of the reduced scale of adoption.
Proactive regulation	Regulations are unclear, and not favourable to rapid widespread adoption of AAM and UAS.
Regulatory timeliness	New regulations are delayed and prevent AAM and UAS adoption.

The UK AAM and UAS landscape: The UK's public and private sectors do not have a strong ambition to promote UAS and AAM, with funds instead spent on different advanced manufacturing sectors, including advanced "conventional" aerospace (i.e. SAF and hydrogen technologies for large passenger airliners). As a result, any UK-based AAM and UAS companies begin to look beyond national borders for funding, skilled workforce, and demand.

AAM use cases remain confined to luxury private hire services and are typically not affordable for the public. As a result, there is a significant delay to any developments in low-altitude integrated airspace and regulations/procedures tailored for eVTOLs, as the very low volume of AAM operations does not justify the significant investment required. In addition, commercial UAS operations are confined mostly to the use cases and levels of 2024. Regulatory delays and a lack of demand mean that a business-as-usual regulatory pathway for BVLOS operations is not in place until 2031, with autonomous operations not possible in an integrated airspace until 2050. Using UAS for last-mile logistics is very limited with only some sporadic adoption after 2036, but there is still a sense of public unease surrounding drone use which hinders adoption.

Overall, the UK future flight sector is not actively backed by the public sector and the public itself, meaning much of the physical and digital infrastructure is not developed, resulting in very low adoption of AAM and UAS in the UK.

The global AAM and UAS context: The global future flight market continues to develop without the UK as a major player. AAM services are developed and successful in other countries with RAM and UAM becoming common place around the world as a means of moving people between and around cities.

Similarly, other countries are able to create regulation and legal frameworks for BVLOS and autonomous UAS operations significantly faster than the UK, leading to a less favourable future flight ecosystem for businesses within the UK. A lack of renewed and long-term funding opportunities for future flight technology and integration further hinders the impact on the ecosystem, leading to AAM and UAS organisations looking abroad to seek investment and operational growth. The resultant impact leads to a heavy reliance on importing of future flight technologies, with very few exports.

AAM market in the UK: Infrequent and minimal eVTOL operations across the UK are anticipated. This is a result of minimal public sector funding, and a heavy reliance on private organisations to progress integration and support the regulator to develop a regulatory framework. There is little communication relating to the benefits and safety of eVTOL operations, resulting in minimal public confidence, advocacy and understanding of the benefits. The only established public use for eVTOLs in this scenario is likely to be linked to movements of people to and from airports, which is likely to remain expensive and inaccessible for many. Private eVTOLs may also be used in small numbers by the wealthy as a means of avoiding congestion in and around cities, with overall demand and flight volume remaining low.

There is a distinct lack of suitable vertiports and EV charging infrastructure due to a lack of investment. This lack of growth dramatically hinders the wider adoption of AAM services in the UK. A lack of investment leads to key future flight organisations leaving the UK for more favourable commercial and regulatory environments. As a result, the UK is dependent on imports.

Overall, this scenario is based on a lack of supply-side growth towards the future flight sector, which creates an ecosystem unable to sustain wider economically viable AAM operations. AAM operations are likely to be limited to the point-to-point transport of high-wealth individuals, and very limited public services such as connections to major airports. This results in the UK importing much of its AAM aircraft and capability, causing economic leakages in the UK. The transport system in 2050 thus sees a very limited integration of AAM and UAS services in comparison with scenario 4 of high sector growth.

UAS market in the UK: The UK UAS market is also characterised by low demand. Some emergency services operations are likely to be carried out by UAS, however these are very limited across the UK. Other use cases may include private sector inspections (such as infrastructure), however the rate of transition from demonstration to in-service capability is very slow. Organisations tend not to have their own dedicated UAS operators or platforms, leading to significant outsourcing to specialised sub-contractors due to platform and training costs along with regulatory approval complexity. The public retains a level of unease surrounding UAS, and continues to have concerns around safety, security and privacy due to a lack of government guidance and information. In addition, there has been little progression of a lower-airspace integration solution, leading to only designated sections of UK airspace approved to support BVLOS UAS operations.

The lack of manufacturing capability in the UK means that most drones are imported with small UK-based manufacturers having to close or relocate overseas to access a more favourable market. The heavy reliance on imports could create a monopoly in the UK market which keeps UAS platform prices high. with UAS prices in this scenario growing at the rate of the CPI.

Scenario summary: In this scenario the lack of sector ambition translates into the supply-side barriers for AAM and UAS not being overcome. This corresponds to low demand because of inconvenient and inaccessible services, leading to low public buy-in. Overall, this results in very little progress in the integration of AAM and UAS into the UK transport network. This is summarised in Figure 39.

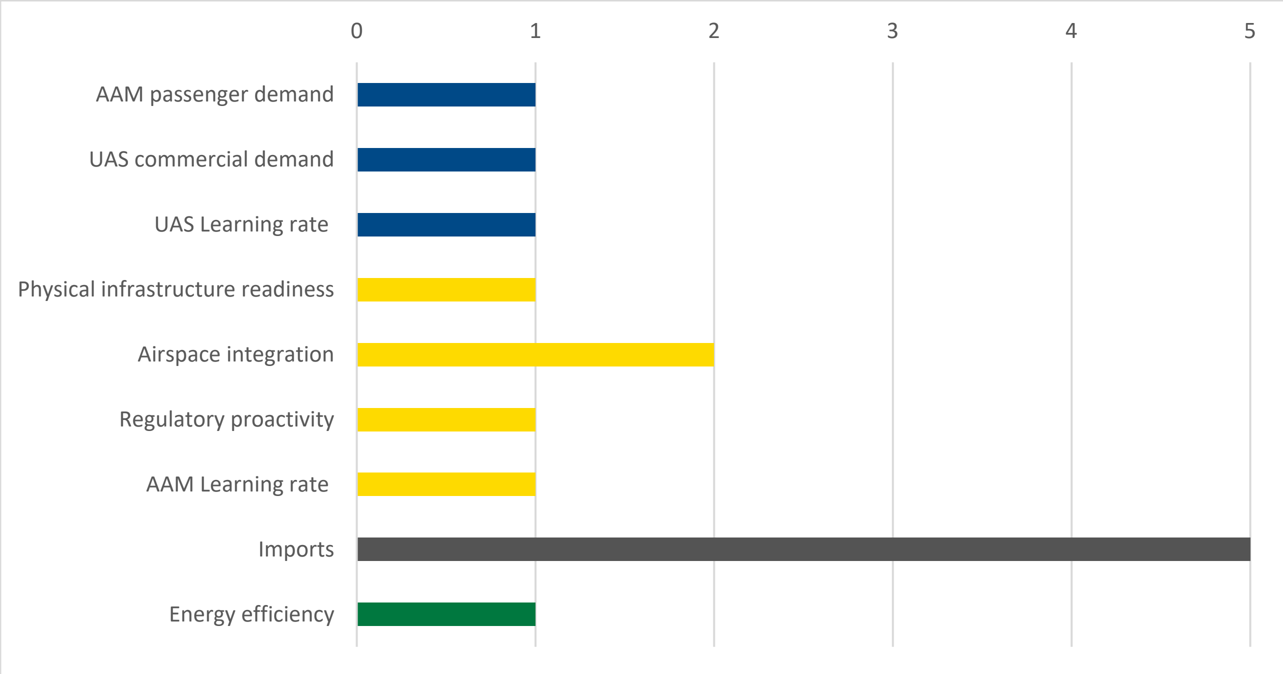

Figure 39: Qualitative assessment for scenario 1.

B.1.2 Scenario 2 – Acceptance by business but not by general public

This scenario relates to a future where industry/businesses have a generally positive view of the future flight sector, but the public has a negative view. This leads to a situation in which there is significant uptake of future flight technologies in the industrial sector for use cases such as infrastructure inspection and maintenance, but little to no uptake in use cases that require direct interaction with the public (e.g. AAM & last-mile logistics). In this scenario, the key future flight stakeholders and government have not succeeded in convincing the public of the benefits that UAS and AAM can bring, either through lack of sufficient education and information dissemination, or through technology demonstration setbacks that influence the perception of the sector. On the other hand, businesses have understood and have first-hand experience of the benefits provided by UAS and AAM and continue to invest in the sector. Regulations in this scenario are tailored towards industrial operations, given the low demand for other use cases. Overall, demand for UAS is significantly higher than for AAM, given the lack of demand for passenger transportation. The state of the uncertainties in this scenario is outlined in Table 11, with positive end states shown in gold, and negative ones shown in red.

Table 11: Uncertainties relating to scenario 2.

Uncertainty	End state in 2050
Long term R&D funding	Significant funding exists for developments in the use cases that interest the private sector, but little funding towards public use cases.
Physical infrastructure readiness	Minimal public infrastructure, widespread drone ports for industry operations, owned and maintained by individual corporations for their own needs.
Future skills supply and demand	Demand for skilled workforce exists within businesses for developing their UAS operations.
Local planning laws	Strong opposition to vertiports, easy for local planners to oppose them.
Future airspace management	Widespread BVLOS corridors enabling large scale UAS operations in segregated airspace. No fully integrated Unmanned traffic management (UTM) due to very low AAM uptake.
End users buy-in	Industrial/business owners and managers are highly interested in UAS and AAM technologies. There is little to no demand from the public.
Proactive regulation	Regulators maintain a proactive approach in collaboration with industry with regards to UAS but are reactive and lag behind in AAM.
Political will	Will to support and fund the sector exists mainly from pressure exerted by large businesses/organisations. Little to no will develop UAS/AAM services and infrastructure.
Diversity of use cases	UAS use cases are diverse with a wide range of industrial use cases, but use of AAM remains limited.
Public/social acceptance	The public is against UAS and AAM. There are strong views that these are nothing but novelty transport options for the wealthy. Concerns around privacy linked to high UAS use remain common.
Proactive regulation	Regulations relating to use cases of interest to businesses are actively developed, but there is little emphasis on integrated airspace for AAM due to lack of interest.
Regulatory timeliness	Regulators promptly develop and address areas deemed of high priority.

The UK AAM and UAS landscape: Businesses are increasingly interested in maximising their operational efficiency, resulting in a high interest in novel technologies. The public instead has little interest in expensive new technologies, with other issues being of more concern.

The future flight sector thus benefits from a strong base of support from the country's industries, resulting in particularly high UAS demand for infrastructure inspection, maintenance, and other use cases. Leveraging the existing future flight ecosystem, businesses can share the clear benefits of using UAS, and in collaboration with regulators help shape a framework to facilitate scale-up of these operations. Competition between businesses, coupled with the development of a regulatory framework and BVLOS corridors enabling business-as-usual BVLOS flights sparks a rapidly growing demand for advanced commercial UAS platforms and infrastructure.

The government does not see the future flight sector as a key priority, although the high demand from large businesses does urge it to act to maintain UK-based companies satisfied and keep them from moving facilities and operations abroad. The importance of UAS in the UK's industry is clear, but there is little to no desire to push public adoption of future flight services. Public view remains highly sceptical, with many being concerned that widespread UAS usage would lead to high security and privacy risks, with AAM instead being seen as nothing but a status symbol transport for the wealthy. The initial high service cost barrier is never overcome due to the low demand and scale of AAM operations.

In summary, the UK future flight sector is largely industry-driven, with regulators also taking a proactive and collaborative approach with industry, but public sector support remains largely reactive and as a response to industry demand.

The global AAM and UAS landscape: The world's leading economies develop at different paces. Amongst the better faring ones, public opinion on new technologies is less pessimistic given the higher growth in household income, but few are enthusiastic.

Across the world, major businesses with capital to invest recognise the operational efficiencies that autonomous UAS bring and collaborate with regulators and UAS developers to accelerate development of the required systems and frameworks. Global demand for UAS in industrial applications grows significantly during the 2030s and 2040s. The relatively gradual increase in UAS numbers and operations allows regulators to act proactively, resulting in a set of regulations that is largely standardised and harmonised across a majority of countries, in part fuelled by the desire of multinational corporations to facilitate their UAS operations across their global networks. In the few countries where public opinion on future flight is less pessimistic, AAM uptake sees moderate growth, but overall numbers and infrastructure remain limited, and costs remain high.

The AAM market in the UK: Demand for AAM in the UK is very low, due to the widespread public pessimism surrounding it. A number of eVTOL models are certified worldwide during the 2030s, and used primarily as luxury point-to-point hire transport, or increasingly as cargo or emergency services aircraft slowly taking up the role of helicopters. By 2050, despite developments in technology allowing larger AAM vehicles to become feasible, the disinterest to invest in infrastructure means that only a couple of scheduled passenger services exist in major cities, with the country seeing at most a couple hundred urban eVTOL flights in a day. Vertiports are few and far between, with strong opposition from local councils and communities making it easy to successfully oppose vertiport construction. Vertiports are mostly seen as a nuisance by many, taking up valuable space that many believe would be better used for other purposes, such as new housing.

In remote communities, opinions on AAM are more positive, as it is seen as a more sustainable replacement for the air services that these communities rely on to remain connected. Several of these routes begin transitioning to eSTOLs/eCTOLs in the 2030s, but the overall volume of AAM traffic generated from these is low. Some logistics businesses make use of AAM vehicles as a regional cargo service, allowing rapid delivery between areas with small airfields or helipads, and emergency services begin to replace their helicopter fleets with eVTOLs once these become more mature technologies in the 2040s. Due to the relatively low volume of AAM flights (similar to current helicopter flights, both in volume and routes), especially in urban areas, they are treated as standard aircraft for airspace management purposes. The volume of traffic does not justify investing in the development of a fully integrated UTM system, and as a result the UK falls behind certain countries in the airspace management field.

Due to the low overall demand in eVTOLs, manufacturers struggle to remain in business. Many close or are purchased by the more successful ones during the second half of the 2030s, creating a market where a few key competitors hold the vast majority of the market share. Competition between the key eVTOL manufacturers is intense, as they each compete for the same limited market opportunities. Many manufacturers pivot away from the passenger AAM market due to negative publicity and lack of demand, focusing instead on cargo or emergency service vehicles. The eVTOL takes up the role of an evolution of the helicopter, rather than a revolutionary new form of transport. As domestic demand in the UK is very low, UK-based AAM companies gradually begin to leave the country and establish presences closer to their target market.

Overall, the AAM sector sees very limited growth due to disinterest and even opposition by the public. A few AAM manufacturers are able to satisfy the limited demand that exists (mostly abroad), with alternative AAM use cases such as cargo and emergency services being explored. The UK's AAM sector is unlikely to be a major player due to limited investment and demand within the country and an unfavourable regulatory landscape.

UAS market in the UK: The UAS market is defined by a significant increase in demand and uptake across the world for industrial applications, with the peak growth rates in demand occurring in the decade of the 2030s. Developments in autonomous systems and regulatory frameworks have enabled UAS to drastically increase the efficiency of many tasks and provide significant cost reductions, fuelling further business interest. By 2050, the UK sees large amounts of BVLOS operations every day, covering a range of industrial use cases ranging from infrastructure inspections & maintenance to emergency search and rescue operations.

This trend is mirrored across much of the world, including many rural areas where fast and frequent UAS flights are able to connect remote locations by enabling rapid transfer of supplies and medical equipment, as well as playing a key role in agriculture. This is enabled in the UK by the regulator's proactive approach with regards to industrial applications, in close collaboration with industry partners. The UK benefits from a developed network of UAS BVLOS corridors, enabling use of UAS for long range inspections and maintenance. The slow pace of AAM development allows the regulator to remain proactive and focus efforts on UAS-tailored regulation. In many countries, health and safety regulations now enforce the use of UAS wherever possible in work involving significant danger to staff, further driving demand. UAS infrastructure is very common across major industrial sites and national infrastructure, where UAS are used for inspections, surveillance, and maintenance. Almost every major UK company now utilises UAS as part of their business model.

In the supply side of the market, the UK has not established itself as a major manufacturer, largely due to the already existing, well-established UAS manufacturers present in other countries which have continued with the lead role in manufacturing of consumer and commercial UAS. However, the UK is host to several companies producing highly specialised UAS for a variety of industrial applications, with the country's developed future flight ecosystem and network providing an ideal environment for such companies to develop in. Although the market share of such companies is not comparable to that of the large consumer UAS manufacturers, the overall growth in the sector means that even highly specialised UAS represent a multi-billion-dollar market.

Overall, a scenario in which businesses have a high interest in future flight, but the public remains pessimistic is likely to see a thriving UAS market worldwide, with the UK carving out a niche likely as developer of specialised industrial UAS platforms, as well as autonomous systems.

Scenario summary: Figure 40 provides an overview of the state of the market characteristics for this scenario. This scenario sees a clear split between UAS and AAM, which reflects in high costs and low demand for the latter, with the opposite true for UAS. Regulators are proactive in developing regulations that enable and support large-scale autonomous UAS operations, given the interest and pressure from businesses. However, AAM is largely seen as a secondary objective by regulators and investors, resulting in slow growth both in demand and technologically. A fully integrated airspace is deemed superfluous due to the lack of AAM operations, with the vast majority of UAS operations confined to specific locations/corridors as required by their tasks which makes segregated BVLOS corridors a suitable solution.

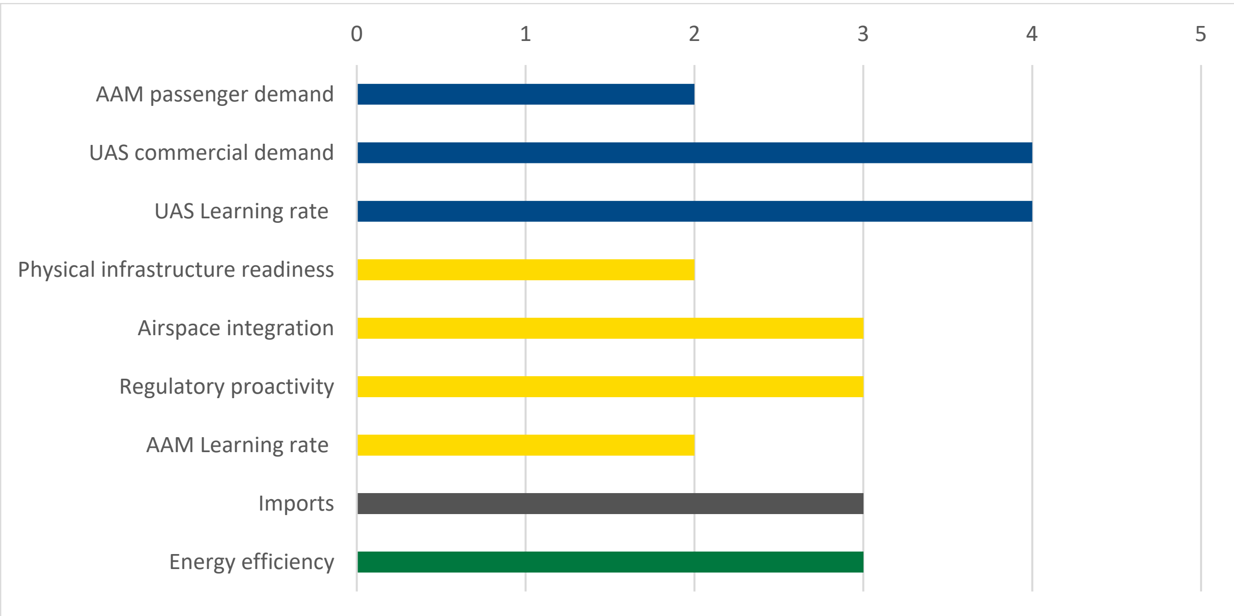

Figure 40: Qualitative assessment for scenario 2.

B.1.3 Scenario 3 – Technology breakthrough in AAM in the UK

This scenario relates to a future where the UK makes a significant technological breakthrough in AAM before the rest of the world, placing the UK as a leader in AAM. The technological advancements support the integration of AAM as a transport service with the facilitation of advanced infrastructure which supports more regular AAM urban and rural services. In this scenario government facilitation is present but not significant with public and private sectors reacting to public perception, whilst R&D funding remains at the same level as in 2024. The public have positive perceptions of AAM but negative perceptions of UAS, driven by privacy concerns. This scenario considers a positive AAM market and a constrained UAS market. The state of the uncertainties in this scenario are outlined in Table 12, with positive end states shown in gold, and negative ones shown in red:

Table 12: Uncertainties related to scenario 3.

Uncertainty	End state in 2050
Long term R&D funding	R&D funding is renewed at 2024 levels. There is still a future of flight R&D programme in the UK.
Physical infrastructure readiness	The UK has a breakthrough in battery technology which creates a step change in AAM supply.
Future skills supply & demand	The rapid growth in the sector causes an initial spike in demand of skilled workforce, which initially struggles to be met, but is caught up by 2050.
Local planning laws	Local planning laws are generally supportive of infrastructure developments enabling UAS/AAM operations, but regional differences exist.
Future airspace management	An integrated airspace system which meets the needs of AAM and UAS and facilitates use in a safe and scalable way.
End users buy-in	Passengers are positive towards AAM services but are less optimistic about UAS services.
Political will	The UK public sector supports future flight but does not make major investments.
Diversity of use cases	Use cases are largely diversified, with technology developments opening up a wide range of UAS and AAM use cases.
Public/social acceptance	AAM is generally viewed as a benefit to society, but reservations exist with regard to the widespread use of UAS, mainly due to privacy concerns.
Proactive regulation	Regulators respond to public perception and are unwilling to regulate for unpopular use cases.
Regulatory timeliness	Regulation development is slowed by legal and ethical debates relating to UAS platforms.

The UK AAM and UAS landscape: The UK government has renewed funding for future flight at the same level as in 2024 and this is sustained until 2050. UK industry makes a breakthrough in battery capabilities for eVTOL, eCTOL, and eSTOL 5 years after the first of these platforms enter service. Smaller lighter batteries allow the UK to establish more regular AAM flights over longer distances, resulting in higher levels of demand due to the increased conveniency for passengers. Improvements in batteries allow eVTOL operators to reduce manufacturing costs and improving energy efficiency. In addition, lighter batteries reduce the weight of the eVTOL which opens opportunities for increasing the payload and passenger capacity of eVTOLs.

The UAS industry is instead slightly hindered by public concerns primarily surrounding privacy. These privacy concerns do not significantly influence demand, but there is considerable debate surrounding how to regulate BVLOS operations which delays the entry into service of a BVLOS capability in the UK. In addition, there are persistent legal and ethical debates surrounding autonomous UAS operations, with this capability not being regulated during the period up to 2050. Overall, UAS demand does not grow quickly but demand growth is steady.

The global AAM and UAS landscape: The UK's breakthrough in battery capabilities occurs before other countries and places the UK as a leader in this technology area. As a result, there is demand from overseas for UK technology which drives exports in AAM charging capabilities. Furthermore, the need for regular AAM services in the UK encourages overseas AAM companies to establish a base in the UK given the more mature state of the UK AAM market.

The global UAS sector continues to grow quickly with other countries regulating for different drone capabilities earlier than the UK. Public trust in UAS in other countries in much higher than in UK with less regulatory debate. As a result, the UK drone industry does not grow as quickly as international competitors.

AAM market in the UK: The UK AAM market experiences strong demand growth in this scenario. Regulators have already approved the operation of eVTOLs in an integrated airspace prior to the breakthrough in charging technology. The breakthrough in battery capability relieves supply-side constraints and allows for eVTOLs to charge quickly in between flights, this allows for more frequent flights around cities. This breakthrough supports the development of vertiports in major UK cities, as well as smaller vertiports connecting outer city areas to the city centres. There are regular UAM services which provide convenience for passengers and decongests city centres. In addition, there are regular RAM services connecting nearby cities. As a result of the improvements in connectivity and reduction in congestion that AAM brings in this scenario, the public perception is largely positive resulting in little to no opposition to plans of expanding the AAM infrastructure network. Passengers are thus highly willing to use AAM as the service is convenient as a result of the highly developed physical infrastructure. Demand is constrained in the early years of eVTOL service, but following the EV charging breakthrough there is a step change in supply which accommodates greater demand.

The UK is ahead of other countries in eVTOL infrastructure, as a result there is a high demand for UK technologies contributing to the export of EV charging technologies. This also acts to attract overseas AAM companies to establish manufacturing bases in the UK, where the demand is high and the AAM ecosystem is highly developed.

Overall, technological breakthroughs have demonstrated that AAM is not only viable but also highly effective, leading to positive public views and significant demand. This is a technology-led scenario, where the technological breakthrough is the key drivers behind a rapid increase in demand. AAM operations rapidly spread across the world and diversify across a wide range of use cases, driving down costs.

UAS market in the UK: The UAS market in the UK experiences steady growth but this is constrained by privacy concerns related to drone delivery as well as legal and ethical debates surrounding autonomous UAS. These concerns do not prevent UAS demand growth, but growth is slower than in the high ambition or the optimistic industry scenarios. Regulators and government are reactive to public opinion and are unwilling to risk rushing regulation for BVLOS operations, as a result BVLOS drones enter service later than expected resulting in lower demand growth. Similarly, airspace integration for BVLOS drones happens slower and with lower capacity than in Scenario 1.

In this scenario UAS are used mainly for site inspections with lower applications in emergency services support with applications limited to less built-up areas due to public concerns surrounding privacy. Drone delivery services are also limited to more rural areas due to airspace management policies. Overall adoption is limited to certain locations and for specific purposes resulting in steady demand growth, but UAS demand is slower than overseas competitors.

Scenario summary: Figure 41 provides an overview of the state of the market characteristics for this scenario. The demand for AAM high amongst the public alike. AAM demand growth occurs as a direct result of a series of key technological breakthroughs which creates a more regular and cost-effective service. The UK can export AAM infrastructure capabilities around the world and is seen as a leader in AAM. Despite this development UAS demand is constrained by lower public trust and reactive regulators results in the UK UAS sector not realising its full potential.

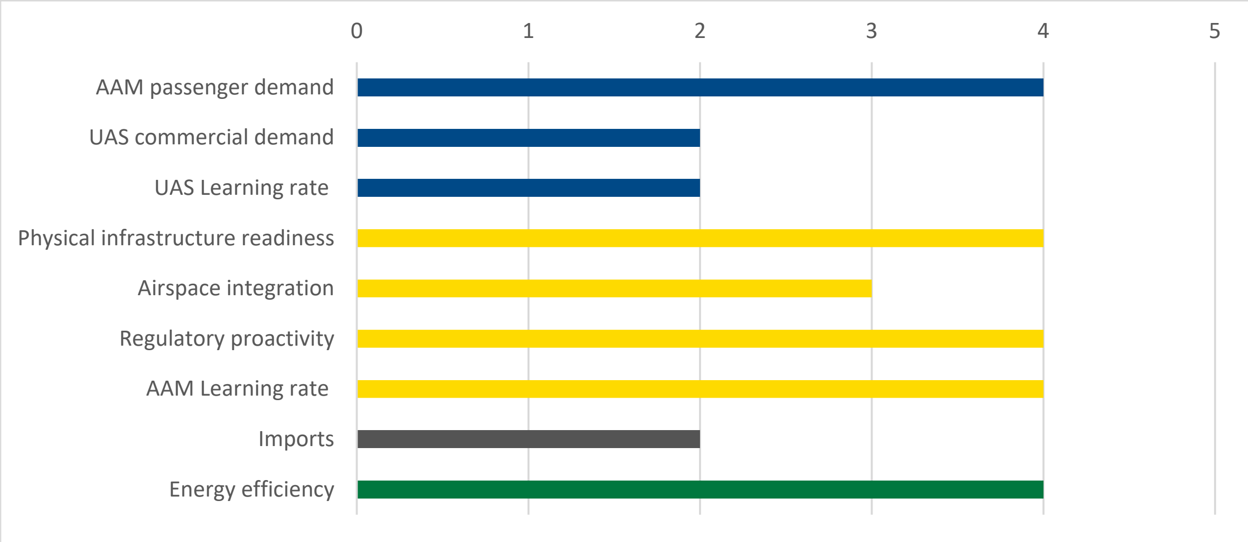

Figure 41: Qualitative assessment for scenario 3.

B.1.4 Scenario 4 – High sector growth

The high supply-side growth scenario represents a future in which the UK public and private sectors strongly believe in the potential of the future flight industry and maintain a high desire for the UK to be a global leader in the sector. This is reflected in an ambitious and well-defined strategy, with relevant public sector bodies such as the CAA all being well funded and with a clear remit and role in helping progress the UK's future flight strategy. The public sector is willing to invest resources into future flight R&D and infrastructure (both physical and digital), as well as coordinate private investments with the continuation of programmes such as the Future Flight Challenge. The regulators and standards agencies act proactively and at pace to create a regulatory framework for AAM and UAS, driven by international pressure to maintain a competitive landscape, enticing the future flight industry. This culminates in the UK possessing the regulatory, physical, and digital infrastructure to accommodate demand for AAM and UAS, with an ambition to create a world leading future flight sector. The state of the uncertainties in this scenario is outlined in Table 13, with positive end states shown in gold, and negative ones shown in red:

Table 13: Uncertainties included in the high UK supply-side growth scenario 4.

Uncertainty	End state in 2050
Long term R&D funding	Clear, extensive, co-leveraged R&D funding beyond 2050.
Physical infrastructure readiness	Efficient development of infrastructure to keep up with demand.
Future skills supply and demand	UK AAM and UAS workforce is highly skilled with no gaps.
Local planning laws	Planning laws are driven by a clear policy and allow for consistent development of future flight infrastructure with support from the public.
Future airspace management	An integrated airspace system which meets the needs of AAM and UAS and facilitates use in a safe and scalable way.
End users buy-in (i.e. demand for AAM and UAS)	End users have high demand for AAM and UAS technologies with an expansion of use cases and investment in the technology.
Political will	Integrated transport plan (road, rail air, maritime) driving and organising investment in the sector, with buy-in from the energy sector to develop the required power infrastructure.
Diversity of use cases	Adoption into relevant industry and public use cases.
Public/social acceptance	AAM & UAS use is widely accepted, with the public viewing it as an overall benefit to society.
Proactive regulation	Future regulations are proactive and delivered with industry buy-in.
Regulatory timeliness	Regulation is prompt and delivered according to existing strategies.

The UK AAM and UAS landscape: The UK public and private sectors are pursuing ambitious growth strategies in advanced manufacturing sectors, including Aerospace. The future flight sector is viewed as the key driver of growth in advanced manufacturing and is accordingly provided with significant resources to develop. This ambition is driven by a desire to be a first mover in the AAM market and create a competitive advantage for the UK in future flight, resulting in increased exports and growth of local businesses, as well as attraction of overseas AAM and UAS companies.

Investment in vehicle technology R&D, digital and hardware systems for airspace integration, as well as vertiports and power provision infrastructure acts to breakdown key barriers and threats highlighted by stakeholders. Barriers such as the lack of existing infrastructure, suitable airspace control systems for large volumes of UAS & AAM traffic, and availability of sustainable power are thus largely overcome. As a result, the UK can fully integrate AAM and UAS into the transport network to fulfil a wide variety of use cases, resulting in a highly integrated transport ecosystem benefitting passengers and operators alike. Barriers such as negative public opinion and availability of workforce with the appropriate skillset are less impacted by increased funding but are nonetheless diminished over time as a result of the large growth of the sector and the overall positive impact it has. The government acts as both a source of investment but also a facilitator in attracting private investment through a range of initiatives and programmes, vastly increasing the investments into the sector fuelling continued rapid growth.

Supply-side growth is echoed by regulators who work proactively with industry partners to create a robust regulatory framework to accommodate AAM and UAS platforms in an integrated airspace. This allows for the integration of eVTOLs, as well as autonomous and BVLOS UAS operations. These regulatory developments help foster a rapidly growing uptake of UAS and AAM, as the reduced barriers to operations make them significantly more attractive options for a wide range of use cases than ever before, including inspections & surveys, deliveries, and emergency services operations.

Overall, the UK has a clear and ambitious objective of being a world leader in the AAM and UAS markets and through both the private and public sector is willing to take the steps necessary to remove supply-side barriers and develop the necessary regulatory, physical, and digital infrastructure to accommodate the integration of AAM and UAS.

The global AAM and UAS landscape: The global future flight sector is highly competitive, with many countries investing in UAS and AAM and aiming to create local ecosystems to entice the major companies in the sector to set up local operations. The readily available funding worldwide having resulted in many new manufacturers competing for a share of the rapidly growing market. Companies are willing to be mobile and relocate to where the best combination of skill base, supply chain, and market exists to gain a competitive advantage.

Despite the high levels of international competition to attract and retain future flight companies and talent, there is recognition amongst governments and national regulators that international collaboration on standards and regulations will benefit the sector as a whole on a global level. An aligned set of international regulations that both ensures safety and allows for accessible testing and development activities will enable operators and developers to easily transfer their services and technologies across the world, further fuelling rapid growth of the sector. Government plans urge regulators to act proactively to develop legislation, resulting in a world where regulatory and legislative developments happen in a rapid and internationally aligned fashion, allowing for significant growth in uptake of UAS and AAM.

Over time, as AAM and UAS technologies become mature and commonplace in the country's leading the race for adoption and integration, the rest of the world also begins to see growing investments in the technology given the success observed, along with reductions in unit costs and technology/regulatory risk. From this point there are a range of ways in which the scenario may unfold, ranging from a case where more manufacturers emerge creating even greater competition driving continuous improvements and lower costs, to one where there is increasing market consolidation resulting in a few large corporations owning much of the market share. The latter may lead to slower growth/stagnation in development because of less competition.

AAM market in the UK: AAM has become an integrated part of the UK transport network, with AAM being used to ease congestion in cities. Major cities create a network of vertiports to connect outer city areas to larger inner-city locations, with regular services creating a steady demand. Vertiports are also set up at UK airports, connecting them to the inner-city areas, as well as connecting airports to one another. Regional air mobility connections exist between certain cities, with services operated by eVTOLs for shorter routes, and eCTOL or eSTOL for longer routes. Overall, AAM is integrated into the transport network alongside taxi services, and existing rail or bus routes.

Government and industry take action to influence AAM demand to overcome perceptual barriers that may exist. This includes implementing public dialogues and advertising campaigns to inform the public of the reliability and safety of eVTOLs, as well as clearly communicating the benefits of AAM in the UK. This results in more passengers willing to use eVTOLs for point-to-point transport. In addition, the public and private sectors actively support the development of services, for example by providing subsidies for AAM routes or pricing services below cost to keep prices low and incentivise passengers in the initial phases of service implementation, with these measures then removed once the service matures and becomes economically viable.

The supply side of the market is characterised by proactive regulation and government facilitation. Regulators work closely with industry and local authorities to create clear design and operational regulations for eVTOLs, including operational procedures that help reduce the environmental impact of the operations. Furthermore, there are significant investments in aerospace R&D to push development of the future flight supply chain and ecosystem. The UK's growing skilled workforce and developed future flight ecosystem begins to incentivise overseas AAM companies to establish manufacturing bases and offices in the UK, and this is further exacerbated by a well-defined and AAM-friendly regulatory landscape. This approach is coupled by a comprehensive power grid modernisation strategy, with the government investing significant funds and effort into developing the UK's EV charging capability from sustainable sources to create a network that can support a fully electric transport system, both on the ground and in the air.

Overall, supply-side growth has created an integrated AAM service which provides a large variety of services to passengers and supports urban and rural connectivity with eVTOLs, eCTOLs, and eSTOLs. Proactive regulation and government facilitation has helped resolve supply-side and demand-side barriers and threats.

UAS market in the UK: By 2050 there is a large-scale use of drones for a wide range of use cases including inspections of national infrastructure, emergency service use cases such as initial response/evidence gathering from accident scenes, surveillance, and search and rescue operations supported by drone stations at multiple locations to improve search and response times. In addition, there is investment by public and private sectors in advertising campaigns to communicate the benefits and safety of using UAS to the public in the late 2020s, which combined with proactive regulation of BVLOS operations results in UAS operations such as last-mile logistics and medical supply deliveries also becoming commonplace by the early 2030s. For the public it is normal to see drones flying in an integrated airspace, and there is little concern about misuse or security concerns, with measures in place to automatically detect and disable suspect drones.

UAS supply is supported by a proactive regulatory approach to support the integration of BVLOS and autonomous drone operations, this regulation is developed quicker and in a more favourable way than in other countries which begins to attract certain UAS businesses to the UK. In addition, developments of drone charging and maintenance stations in cities and around UK national infrastructure provide a vast network enabling long range BVLOS operations, driven by government and industry investment. Increases in demand and public use provide the incentivisation of Small-Medium Enterprises (SMEs) and service providers for a variety of UAS services such as ad-hoc site inspections and surveys, resulting in a strong base of specialised UAS service providers and SMEs in the UK.

Overall, an ambitious future flight sector has overcome many of the supply and perceptual barriers for BVLOS and autonomous UAS operations, and in addition the public sector becomes a major user of UAS.

Scenario summary: Figure 42 provides an overview of the state of the market characteristics for the high ambition scenario. In this scenario, demand for AAM and UAS is high with the highest level of growth predicted to be between 2028 and 2038, resulting from the introduction of routine eVTOL and BVLOS UAS operations, along with the introduction of autonomous UAS platforms. Demand will then lessen up to 2050 due to diminishing returns. Infrastructure and regulatory readiness are high, which translates to a reduction in supply-aside barriers allowing platforms to enter service as per the timeline laid out in the FFIG action plan. Significant investment in R&D produces improvements in energy efficiency and cost reductions in both AAM and UAS.

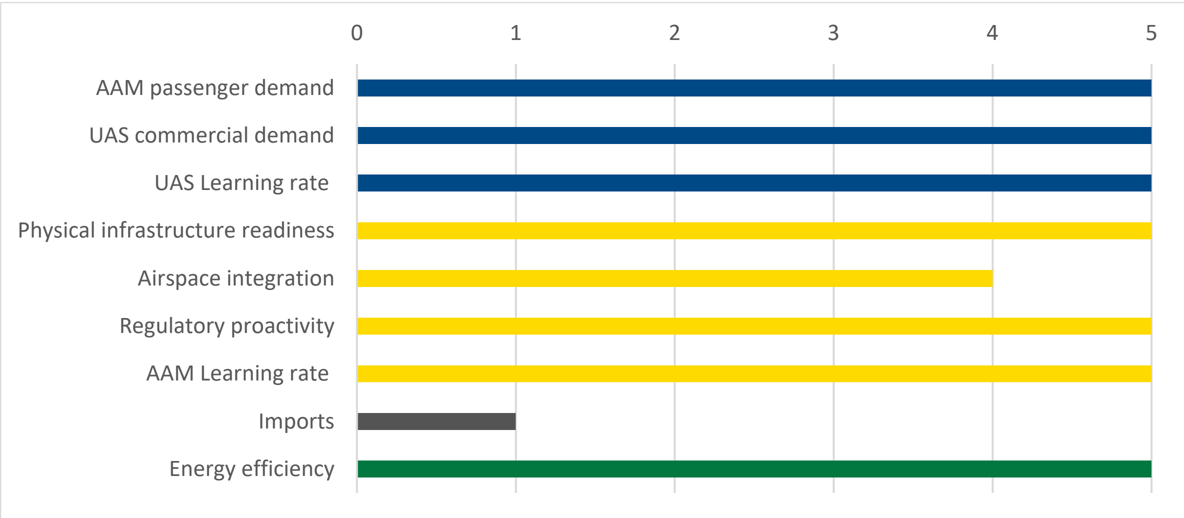

Figure 42: Qualitative assessment for scenario 4.

Annex C - Economic model logs

C.1.1 Uncertainty log

Table 14: Economic model uncertainty log

ID	Description	Impact	Mitigation of uncertainty
1	Uncertainty relating to UAS prices and the range of UAS products makes estimating sales revenue uncertain.	Likely over or underestimate sales revenue from UAS platforms and components	UAS prices have been derived using a Monte Carlo simulation of current and historical drone prices. The P50 value from this simulation has been used as the BVLOS drone price, and the P95 has been taken as the autonomous drone price. The Monte Carlo simulation has been carried outside of this model.
2	Current RAM and autonomous AAM vehicle prices are unknown due to no currently available RAM vehicles.	Likely over or underestimate sales revenue from RAM vehicles	UAM price has been multiplied by passenger ratio between RAM and UAM to get an RAM price. The RAM and UAM price have been multiplied by the autonomous multiplier (ratio of UAS to autonomous UAS price).
3	The future state of the UK economy is uncertain	Impact may be overestimated if the UK experiences a downturn	This will be resolved through sensitivity analysis to model the UK under a high and low economy. This will vary GDP and household expenditure by +/- 0.5% as per the common analytical scenarios
4	The future of AAM and UAS funding is uncertain following the end of FFC.	Uncertainty relating to funding of FFC will affect market signalling and effect development of the technologies.	Each scenario has a different narrative surrounding R&D funding. The high sector growth assumes high levels of R&D funding from public and private sectors, whilst the low sector growth scenario assumes there is low funding.
5	Future EV charging capability readiness may not support AAM and UAS.	Future EV charging capability readiness may not support AAM and UAS.	Each scenario includes a range of assumptions surrounding infrastructure readiness. In the high sector growth scenario, it is assumed that EV charging is ready before the aircraft are developed. Within the low sector growth scenario, the EV charging is not ready.
6	Uncertainty relating to the nature and quantity of required skills to support AAM and UAS.	Production costs will be influenced by the skill levels of the future of flight workforce, if skill levels are not understood then production cannot be understood.	The high sector growth scenario includes a highly skilled workforce which results in lower AAM production costs through a higher learning rate, whilst the low sector growth scenario considers a situation where a lack of investment has led to highly skilled individuals working in other advanced manufacturing sectors.

7	The full array of AAM and UAS use cases is vast and will develop into the future.	Impact may be missed if a use case sees higher demand than expected.	This study is based on 5 broad use cases to bound the AAM and UAS market. A catch-all "other use case" has been added to the UAS market to account for any undefined use cases. This means the full UAS commercial market is captured.
8	It is not known how the public will react to AAM and UAS operations in an integrated airspace.	Public perception will dictate the willingness to use AAM and UAS services. This must be considered to produce an adequate estimate of demand.	This uncertainty is varied across the scenarios and across technology areas to get a full spectrum of public acceptance.
9	The details of future regulation and the timing of that regulation is uncertain.	Regulations will influence production costs and entry into service years, as well outlining operational standards.	The timing of regulation is expressed in the scenarios and is baselined from the FFIG action plan. It is assumed that regulation either approves or disproves of a capability rather than considering design and requirements
10	With several potential end users, the level of buy-in is uncertain and dependent on a complex set of issues.	End users buy-in is the principal determinant of demand. If end user buy-in is not adequately accounted for then demand will be over or underestimated.	Each scenario treats each group of end users differently. For example, the technology breakthrough scenario focuses on passengers, whereas the acceptance by business creates a distinction between different end-users and different use cases.
11	Future airspace integration plans for future flight may change in the future.	Airspace integration and air traffic control plans will dictate what can fly and when it can fly.	For simplicity it is assumed that airspace integration does not regress during the forecasting period. The scenarios themselves capture a range of airspace integration measures and magnitudes.
12	Use of existing infrastructure for vertiports is not clear.	Uncertainty relating to the use of existing infrastructure also creates uncertainty in the overall infrastructure requirements in AAM.	In the scenarios it is assumed that existing airports are converted to vertiports before new infrastructure is created.

C.1.2 Assumptions log

Table 15: Economic model assumptions log

ID	Assumption description	Reason	Impact on modelling	Stability of assumption
1	UAS and AAM base prices held constant in real terms. The only changes occur as a result of learning improvements which is applied through Wrights learning curve.	Covers the uncertainty in drone price and is linked to a core dataset. Using the learning rate accounts for skill improvements which are adjusted in each scenario.	High	Medium
2	Autonomous UAS will replace some of the demand for BVLOS and VLOS operations.	Autonomous UAS represent a further removal from humans in the loop and represents greater opportunities for businesses.	Medium	Medium
3	There is one docking port per UAS drone.	This is being used to calculate drone infrastructure without double counting vertiports	High	High
4	UAS demand growth during each stage of the industry life cycle is linear.	UAS demand is highly seasonal with registrations dropping every December during the renewal period. Assuming a linear trend corrects for seasonality.	Medium	Low
5	UAS and AAM demand follows a staged industry life cycle. The cycle can be described as: - Current trends: continuation of current trends - Introduction: Slow demand growth - Growth: fast demand growth - Maturity: Slower demand growth - Saturation: very slow demand growth	Accounts for changing demand following early adoption, and changing demand patterns up to 2050	High	High

6	Regulatory barriers do not persist after entry into service is approved.	Following improvements in regulatory approvals and future frameworks there is not a regression in the regulation of future flight.	Medium	Medium
7	Airspace integration measures (e.g. air traffic control, safety systems, etc) are able to accommodate 100% of potential demand.	A mixture of technology, regulation, and operational procedures are required to enable a future aviation system.	Low	High
8	The taxi service market in the automotive industry is a proxy for the AAM market.	The AAM passenger market does not currently exist, presenting a lack of data. Taxi market data is used because they are substitutes for private transport.	High	Medium
9	AAM taxi substitution effect is comprised of willingness to use, infrastructure readiness and vehicle journey distribution.	These three components are likely to be the most impactful non-price factors effecting the adoption of AAM passenger services.	Medium	Medium
10	During the growth period the improvements in technology will reduce the nominal price.	Common in early adoption and growth stages as economies of scale produces a price effect captured by the learning rate.	High	Medium
11	One parking/charging spot is needed for each AAM vehicle.	If the AAM vehicle is not in use, it will be parked or charging.	Low	High
12	RAM and UAM vehicles use the same vertiports.	Large vertiports will likely have RAM and UAM vehicles operating out of them to provide access to a range of routes.	Low	High
13	10% of AAM journey time the vehicle is not operating at max cruise speed.	This accounts for take-off, landing, acceleration and deceleration periods.	Low	Medium

C.1.3 Dataset log

Table 16: Economic model datasets log

ID	Parameter	Dataset	Date accessed	Notes
1	Gross domestic product 2023	ONS Gross domestic product: chained volume measures: seasonally adjusted £m	23/04/2024	Up to 2023. Data from 2019 to 2023 is also used to calculate UAS income elasticity.
2	Population	ONS mid-year population estimates	23/04/2024	Up top 2022, mid-year population not yet produced for 2023.
3	GDP per capita	ONS GDP per head, chained volume	23/04/2024	Up to 2023.
4	Long term economic determinants	OBR long term economic determinants	23/04/2024	Projections of GDP per capita, CPI, and population
6	Discount rate	HMT green book	23/04/2024	
7	Drone IDs	Drone and model aircraft registration and education scheme (DMARES)	20/03/2024	Provided by DfT
8	Drone prices	Data collected from Drones direct, RPAS report (2016), and drone procurement websites.	30/04/2024	Various data points were collected from drone procurement websites and simulated using Monte Carlo simulation. The p50 price from this analysis has been added into the model.
9	Drone commercial split	Drone users report produced by drones direct	29/04/2024	
10	Taxi Demand 2002-2022	Mode of travel	29/04/2024	Average annual number of trips and miles per person using a taxi.
11	Number of PHVs and taxis	Licensed PHVs and taxis since 1965	29/04/2024	Data from 2017-2023 is used, excluding any outliers.

12	Industrial codes for future flight industry	Brycetech AAM evidence review	05/02/2024	Provided by DfT
13	Autonomous UAS price	Data collected from Drones direct, RPAS report (2016), and drone procurement websites.	25/04/2024	Various data points were collected from drone procurement websites and simulated using Monte Carlo simulation. The p95 price from this analysis has been added into the model.
14	DJI Matrice 300 RTK prices	Data collected from multiple review articles dated each year from 2019 to 2023 to compare price changes over time	25/04/2024	Used to calculate UAS price elasticity of demand.
15	Drones per business	DfT. (2017). Unlocking the UK's high tech economy: consultation on the safe use of drones in the UK.	19/06/2024	
16	Taxi travel distance per person	Average number of trips, stages, miles and time spent travelling by mode: England, 2002 onwards	02/05/2024	Used to calculate the average annual taxi demand.
17	Taxi journey distribution	Average number of trips and average distance travelled by trip length and mode: England, 2002 onwards	02/05/2024	Taxi journeys greater than 50miles are classified as RAM journeys.
18	Total licensed PHVs	Licensed taxis and licensed PHVs: England and Wales from 1965	02/05/2024	
19	AAM vehicle max speeds	Brycetech AAM evidence review	02/05/2024	Provided by DfT
20	Drone use case split	DfT. (2017). Unlocking the UK's high tech economy: consultation on the safe use of drones in the UK. Emergency Drones Market Size, Share and Trends Analysis	07/06/2024	Emergency services support UAS uplifted from 2017 consultation.
21	Aerospace learning rate	https://nano.uantwerpen.be/nanorefs/pdfs/OA_10.1016j.rser.2020.109937.pdf	19/06/2024	
22	Vertiports information	To take off, flying vehicles first need places to land (mckinsey.com)	19/06/2024	
23	UAS import parameter	The Top 25 Drone Companies in 2024 - Drone U™ (thedroneu.com)	19/06/2024	

24	Social view of AAM technology	Ipsos report (publishing.service.gov.uk)	19/06/2024	
25	Infrastructure patrol annual distance	What do National Grid's helicopters do? | National Grid Group	19/06/2024	
26	Helicopter average kgCO2/km of inspection	How much CO2 is saved by switching from helicopters to drones for power line inspections? (airpelago.com)	19/06/2024	
27	Average speed of helicopter during inspection	The "flying guardians" of high voltage on a helicopter to monitor the electricity grid | Lightbox (terna.it)	19/06/2024	
28	Helicopter flying hours for inspections	NGED Air Power - Homepage (nationalgrid.co.uk)	19/06/2024	
29	Hours of search and rescue (SAR) flying	Search and Rescue Helicopter Statistics: Year ending March 2023 - GOV.UK (www.gov.uk)	19/06/2024	
30	SAR helicopter values	How Green Is Satellite Monitoring? Let's Do the Math | LiveEO (railway-news.com)	19/06/2024	
31	Aviation fuel efficiency annual improvements	ENVReport2022_Art7.pdf (icao.int)	19/06/2024	
32	Number of commercial delivery vehicles	Van statistics: 2019 to 2020 - GOV.UK (www.gov.uk)	19/06/2024	
33	Average packages delivered by UAS per hour	Drone and deliver (aerosociety.com)	19/06/2024	
34	Average packages delivered by LGV per hour	Yodel (yodelopportunities.co.uk)	19/06/2024	
37	Annual packages delivered	UK parcel shipping: annual volume 2013-2023 | Statista	19/06/2024	

38	Average emissions per delivery	Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery - PMC (nih.gov)	19/06/2024	
40	UAS energy used per km	Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery - PMC (nih.gov)	19/06/2024	

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