Global Urban Air Summit

WHITEPAPER

Urban Air Mobility Outlook

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Contents

3 SUMMARY

4 INTRODUCTION

5 ABOUT THIS WHITEPAPER

5 SEGMENTS

6 MARKET PROSPECTS

9 KEY CHALLENGES

Urban Air Mobility (UAM) is right at the top of its hype-cycle at the moment, with scores of programs at varying degrees of maturity in existence around the world - and continuing to emerge. UK industry is keen to be a leading player in this exciting, and potentially disruptive, sector of Aviation. In order to do so, it has to better understand a number of dynamics in the emerging UAM Market.

Is it all hype or a sector worth pursuing? If so, when will it emerge as a revenue generating market?

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ADS Urban Air Mobility Group Market Report

SUMMARY

This thought paper is intended to be stimulating for the UK UAM community when considering market viability, barriers, constraints and enablers in this emerging sector of aviation. Derived from background material and the expert opinions of the ADS Urban Air Mobility Group members, the paper is deliberately speculative in its findings and conclusions. It delivers a precise of the credible UAM market and landscape reports published to date.

The paper aims to provide an enhanced perspective on the realism, potential, scale and timings of the UAM market thus promoting realistic targets and development of offerings. Without such insights market actors could expend limited resources on evaluating the market or basing business decisions on very limited data or inconsistent publicly expressed views.

However, more analysis is required to provide a full market sizing. Only a detailed and structured analysis complete with robust and transparent methodology, and credible data sets will be sufficient to underpin conclusions.

Its scope encompasses the global market for urban and sub-regional electrically and hybrid-electrically propelled passenger air vehicles. Although not strictly 'urban', the group feels that sub-regional vehicles will contribute developments in technology, operational knowledge, social acceptance, and earlier entry points to market, that will benefit other segments.

A subgroup of ADS's Urban Air Mobility Group members with interest in the UAM market and business models, used consensus reaching approaches to identify a number of market segments defined by use cases and vehicle types. It went on to establish a shared view on market potential and the challenges of constraints faced by each of the use cases.

The timing of these challenges led the group to conclude that the different use cases are likely to be realised, if at all, in the following order: Sub-Regional hybrid-electric/electric aircraft, HNWI Transports followed by Into City and, lastly, Around City.

Although the thought paper approach led to conclusions about relative timing of use cases, detailed analysis of constraints and the time to overcome them would be required to better understand market entry timelines.

In terms of number of vehicles, the group anticipates the greatest number being required in the Around City case should the challenges to it be overcome, followed by Into City, Sub-Regional and then HNWI Transports.

About ADS and its Urban Air Mobility Group

INTRODUCTION

ADS is the UK trade organisation representing the aerospace, defence, security and space sectors. ADS is focused on representing the interests of these valuable wealth producing industries in the UK and overseas to key stakeholders, government and the media. Farnborough International Limited, which runs the Farnborough International Airshow, is a wholly owned subsidiary.

ADS has six business priorities: (1) Improve the image and profile of our industries; (2) Influence the policy debates of most importance to our industries; (3) Support UK manufacturing and our industries' supply chains; (4) Encourage investment in technology and innovation; (5) Support business development opportunities nationally and in priority international markets; and (6) Increase Member value. Supporting the delivery of these objectives, ADS has established a number of Boards, Groups and Committees that inform and shape ADS's agenda and activities. One of the newest amongst these is the Urban Air Mobility (UAM) Group.

The UAM Group was established to bring together UK stakeholders that have a shared interest in developing the sector in readiness for the emerging global market opportunities. The Group aims to jointly understand the market opportunities, barriers and constraints to access those opportunities, and collaborate on specific pre- competitive activities. The Group comprises over 60 organisations from across ADS's members, established aerospace businesses, start- ups, SME 'primes', academia, associations, funding bodies, government, government agencies, and other key stakeholders.

Given the breadth of developments that are needed to establish UAM services, from infrastructure to vehicle technology, and from regulations to new business models of aviation, the Group was split into several working groups to develop thinking and recommendations around these diverse areas. Through workshops, the aim of each working group is to deliver output that the core participants deem value- adding and enabling for the wider sector. The working groups are all open to the wider members of the UAM Group, with output being shared, for review and input with the wider Group. Through this process, the outputs of the UAM Group are considered a broad UK consensus.

ABOUT THIS WHITEPAPER

With the application of technical and business innovation, some suggest that this yet-to-emerge market presents enormous potential to disrupt mobility services, speed up travel, reduce aircraft emissions, deliver customer benefits, realise economic value and create entry points for new suppliers in the air transportation market.

Finding public information that gives the confidence to make business decisions on is not easy. This report describes the findings of a group of aerospace and aviation experts from a wide range of backgrounds and organisations that took a reasoned approach to arrive at some consensus views.

SEGMENTS

Rather than restricting our thoughts to one type of vehicle or use case, as several of the studies reviewed have done, the UAM Group is considering the different use cases that exist within the umbrella of Urban Air Mobility and the differing vehicles that may serve them. The potentials being addressed are identified in Figure 1.

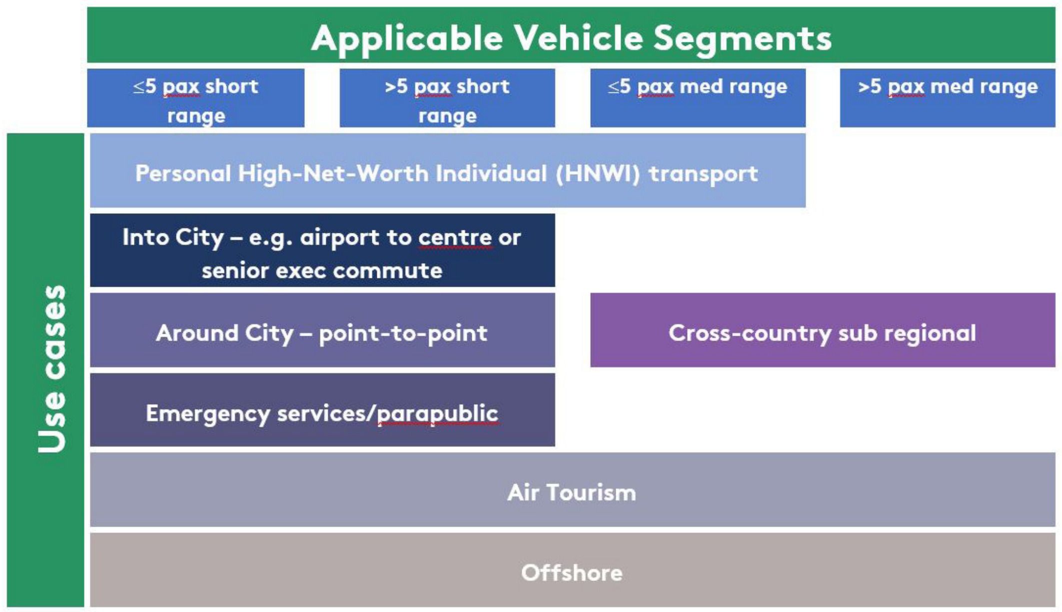

Figure 1 - vehicle segments and use cases

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MARKET PROSPECTS

Even before the UAMs currently in development approach certification, we have some inkling of what benefits they might deliver. A privileged few in São Paulo exchange $500 to $1,500 to convert a four-hour ground commute into a 10-minute helicopter ride. New technology is promising to make such benefits available to a wider spectrum of users in a wider range of cities with lower noise pollution.

There are a number of landscape reports in the public domain that can help us understand the potential for the market. Only a few of them actually provide market numbers, with even fewer having transparent or credible methodologies to back those numbers up.

The numbers put forward in these documents vary by many orders of magnitude, which reflects different approaches and the fact that this is a market yet to emerge. As well as scale, the predicted time for the market to emerge diverges considerably. In truth, the future market scale and timing is yet to be credibly established across any of the identified segments.

The differences are partially explained by a variety of scopes of use cases and vehicle types being considered in the reports.

To be confident of market size and timing, more detailed and structured analysis is required with transparent methodology and conclusions.

Here, we attempt to extract a few useful highlights from some of these reports.

In its paper, "The Last Mile to Autonomy", Oliver Wyman suggests a global potential autonomous air vehicle market value of around $50bn in 2020 and around $100bn by 2030 [1]. This includes military, personal and commercial drones. The paper anticipates the arrival of autonomous "Taxi fleets" and "Commercial aircraft" in the early 2020s. A review of the challenges faced in these markets later in this paper shows this to be a very optimistic view.

[1] *MOUKANAS, H. & THIBAULT, G., 2018, "The Last Mile to Autonomy", Forbes, 5th February 2018*

BCG identifies four different scenarios in "The Aerospace Industry isn't Ready for Flying Cars"[2] . These are described as:

- Toys of the rich - Supplement helicopters; limited use
- Airblack - Replace car service, providing hub-to-hub transportation on a small number of key routes
- Mass transit - Replace mass transit with hub-to-hub service on many urban routes
- The Jetsons - Replace cars with door-to-door service

What is particularly interesting about these cases is that they are not mutually exclusive. Although 'The Jetsons' is considered an extreme scenario, the other three are not dissimilar to our own HNWI Transports and Into City use cases.

"The Future of Vertical Mobility" published by Porsche Consulting predicts demand for 500, 2,000 and 15,000 passenger electric Vertical Take Off and Landing (eVTOL) drones in 2025, 2030 and 2035, respectively. [3]

Demand for passenger drones is predicted by Roland Berger[4] to rise from zero in 2020 to 98,000 in 2050 based on an assumption of 1,000 drones per city using Munich as a sample case that is extrapolated to a further 97 global metropolitan regions with at least two million people and high GDP per capita.

A McKinsey paper [5], projects a base case for an annual flying taxi operator market of $1.6bn by 2040 and a more optimistic scenario for a $500-$600bn market enabled by all types of market players cooperating to overcome key challenges.

No reports identified addressed the demand in our other use cases but the demand for Sub-Regional hybrid-electric/electric aircraft is expected to be somewhere between that for HNWI Transports and the larger Into City and Around City cases. This would put it in the region of 10,000 aircraft in the global fleet.

The consensus suggests a global fleet of the order of magnitude of tens of thousands in our broad scope of urban air vehicles including eVTOLs and air taxis.

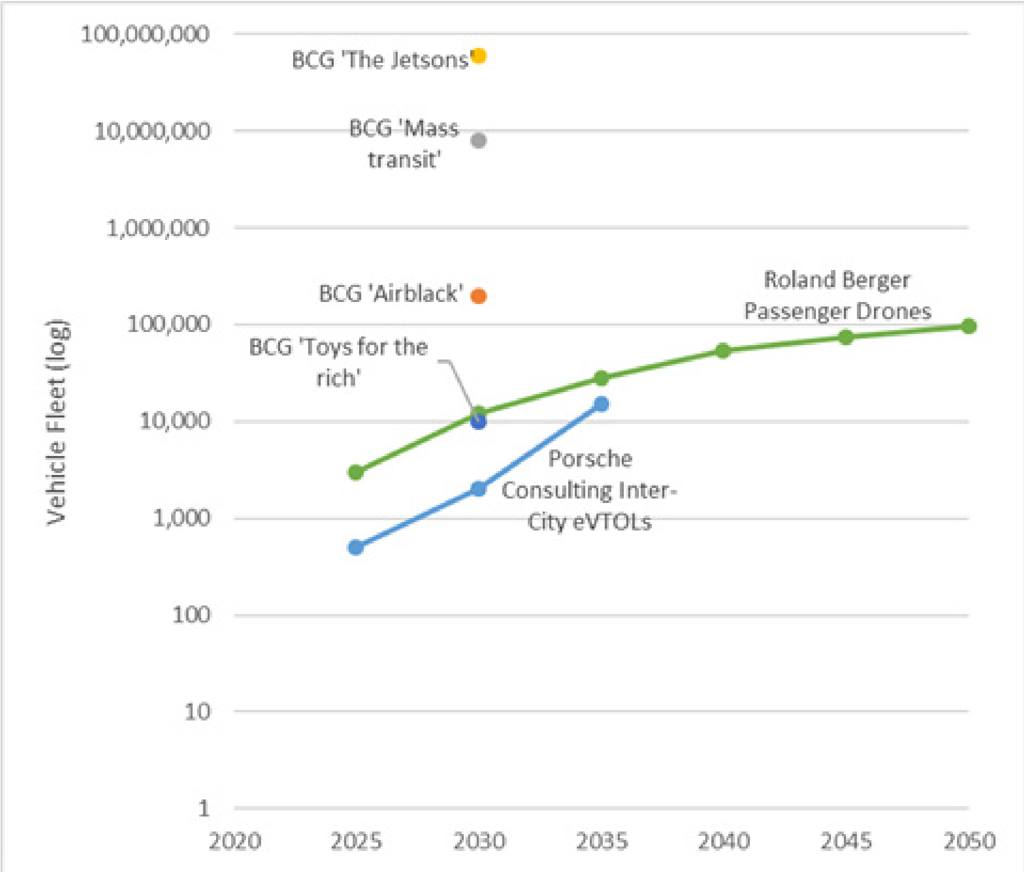

Figure 2 - vehicle demand predicted by public reports

[2] AARONSON, M., MESTER, M., MALLORY, G., & HATTORI, S., 2018, "The Aerospace Industry isn't Ready for Flying Cars", Boston Consulting Group, 7th June 2018

[3] PORSCHE CONSULTING, 2018, "The Future of Vertical Mobility"

[4] ROLAND BERGER, 2018, "Urban Air Mobility – The rise of a Mode of Transportation", November 2018

[5] RIEDEL, R. AND SAHDEV, S., 2019, "Taxiing for Takeoff: The Flying Cab in Your Future", McKinsey&Company, January 2019

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KEY CHALLENGES

To take its own view on the likely timing of the realisation of each use case, the subgroup considered the constraints that applied to all cases. These were determined to be:

Business economics
- Challenges to the economic viability of applicable business models
- Including Continuing Airworthiness Management (CAM).

Infrastructure
- Landing/take-off facilities
- Fueling/charging facilities
- Delivery of unscheduled maintenance including dealing with Aircraft On Ground (AOG)etc.

Daily/seasonal demand pattern
- Are there peaks and troughs that make operation challenging because of utilisation rates or non-revenue flights.

Weather impact
- On being able to operate at all
- On tolerability for passengers

Technology
- Required for vehicles performance, operation, Air Traffic Management (ATM), monitoring & maintenance and infrastructure.

Security
- Passenger screening before boarding
- Cyber security to prevent unauthorised interference with vehicles.

Social acceptance

Legislation & regulation
- Including certification, operation, CAM, inspection and maintenance.

Air Traffic Management (ATM)

Competition
- From other modes of transport including advances in technology.

Environmental impact
- Noise footprint
- Emissions
- In the very long-term, beyond the timescale considered, energy consumption per person may limit the use of air transport.

Manufacturing

The discussion of the challenge of each constraint for each use case can be found in the appendix. The results are illustrated in Figure 3 to Figure 6.

The Sub-Regional case relies on existing rules and infrastructure and its challenges are medium in the short-term, so it could be realised in the next five years.

The HNWI Transport could be realised in a similar timescale but is never likely to achieve any great scale.
Because the high challenges presented by the constraints in the Around City case, it is predicted to be the last use case to be realised at any scale and this could be beyond 2030.

The Into City case has significant challenges but not as great as the Around City case and would be expected to be the first of the two to be realised.

Although the thought paper approach led to conclusions about relative timing of segments, detailed analysis of constraints and the time to overcome them would be required to arrive at more credible timings.

Challenge of constraints for the Sub-Regional case

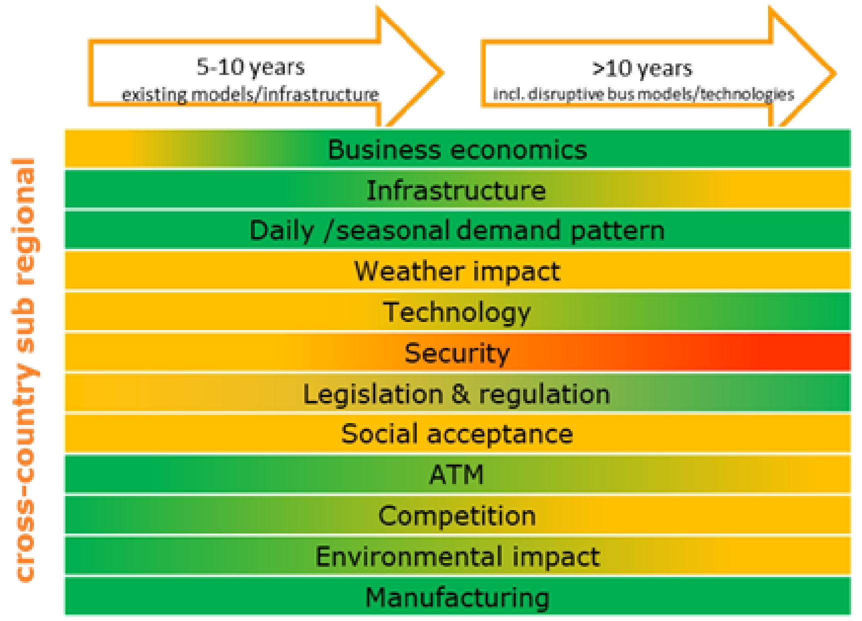

Figure 3

Assumptions

- Generally fixed-wing, conventional take-off and landing
- Operated from existing airfields
- Scheduled thin routes and some chart/on-demand.

Business economics

- Lower capital and operating costs than existing commuter aircraft
- Significant number of airfields available in developed markets like N. America and Europe
- Relatively easy to model demand using mode substitution analysis
- Including CAM.

Infrastructure

- Little additional infrastructure required
- Charging/fuelling facilities required at landing points
- Could be become constrained if growth is high.

Daily/seasonal demand pattern

- Not significant.

Weather impact

- Similar to commuter aircraft.

Technology

- Assumed hybrid followed by all-electric delivering increasing cost and environmental advantages
- Autonomy not likely to be required for business case but it could offer further cost benefits.

Security

- Similar to that for current commuter flights
- If autonomy were to be introduced, greater cyber security would be required.

Legislation & regulation

- Since new technologies and configurations will need to be certificated, there will be near term challenges to overcome.

Social acceptance

- Increased flights at smaller airports could provoke a negative response but this is likely to be mitigated by quitter aircraft to some extent.

ATM

- Existing rules would apply
- High growth or the introduction of autonomy could create challenges in the long-term.

Competition

- Depends heavily on the total journey time benefit versus cost when compared to other modes of transport
- In the long-term there could be substitution to other modes including autonomous road vehicles and improved rail services.

Environmental impact

- In the short-term, likely to be seen as 'greener' than current aircraft
- High demand growth would likely lead to challenges on the energy effectiveness of flight over ground transportation.

Manufacturing

- No significant challenges anticipated.

Challenge of constraints for the HNWI Transport case

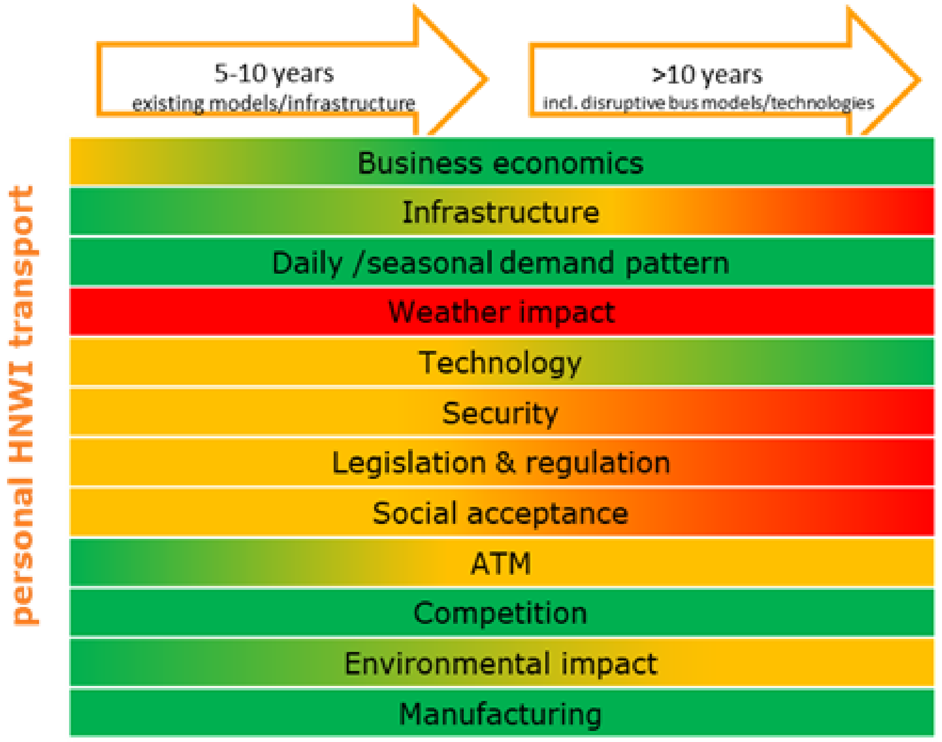

Figure 4

Assumptions

- Initially playthings of the rich. When regulation allows more flexibility of use, can deliver time-saving value similar to corporate helicopter
- Relatively low utilisation
- Anticipated as individually piloted initially.

Widespread city use relies on automation and implementation of and acceptance of Around City case.

Business economics

- Including CAMO
- If available, it will sell. Since the targets are HNWI, there is price insensitivity. This is a determinant of numbers rather than timing.

Infrastructure

- Charging/fuelling facilities
- Delivery of unscheduled maintenance
- Landing 'pads'
- Assumed will initially rely on existing GA infrastructure
- Ultimately, user expectation will develop to include landing at ultimate city destinations rather than a city hub.

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Daily/seasonal demand pattern

- Key benefit is convenience for individuals so utilisation rate has little impact.

Weather impact

- Lightweight and relatively low power margin leads to high impact of wind turbulence
- Automation will have a positive impact in the long term
- Technology impact likely to be counteracted by long-term user desire to operate freely in cluttered city environment.

Technology

- Power margin or energy reserve likely to be limiting factors for all-electric vehicles. Hybrid vehicles assumed first to market
- Assumed initially piloted and individually commanded, ultimately autonomous and centrally managed for ATM in urban environment
- Automated pre-flight inspection required if pre-flight inspection mandated.

Security

- Initially, security challenges as for current GA market, in long-term, dense city operation would present high challenges.

Legislation & regulation

- Assumed to be initially certified and regulated with existing or close to existing rules. Since new technologies and configurations will need to be certificated, there will be challenges
- Longer term, higher density of operations required for city usage will present greater challenges for UTM operation.

Social acceptance

- In the long-term, social acceptance for flying over cities is likely to rely on an Around City service being available to all, else 'it is not for me'. So the challenge is high and overcoming it is reliant upon the success of the Around City use case.

ATM

- In the short-term, assumed to operate under current GA system with piloted vehicles
- In long-term, ATM challenge similar to that for helicopters at present. Success of Around City ATM challenge would overcome this.

Competition

- Separation from mass transit and prestige are significant benefits that restrict the relevance of alternative modes of transit.

Environmental impact

- In short-term, assumed that alternatively powered vehicles have environmental benefits over helicopters they are likely to replace
- In the long-term, use over populated areas will be heavily dependant upon the level and nature of noise generated.

Manufacturing

- Low-volume anticipated, manufacturing challenges will be limited.

Challenge of constraints for Around City case

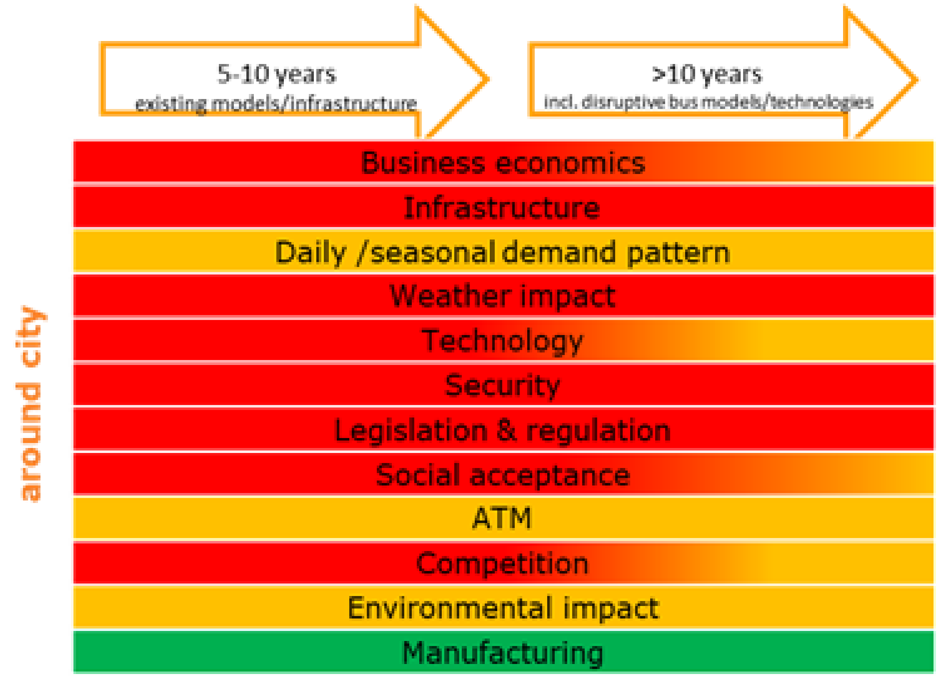

Figure 5

Assumptions

• Mobility as a service, air-taxi service in the urban environment

Business economics

• Viability relies on confidence of becoming autonomous, high utilisation rate
• Only economic at scale
• Attractiveness to the user highly dependant on the balance of cost and total journey time. Requires high number of landing points in any city
• Including CAM.

Infrastructure

• Viability relies on reaching a minimum threshold of network nodes (landing points) in any city
• Charging/fuelling facilities required at landing points
• Delivery of unscheduled maintenance particularly AOG could be significant issue.

Daily/seasonal demand pattern

• Very high demand at peak times requiring high number of non-revenue flights to re-position aircraft.

Weather impact

• Lightweight and relatively low power margin leads to high impact of wind turbulence
• Automation will have a positive impact in the long term.

Technology

• Assumed all-electric is required for acceptability in urban environment
• Power margin or energy reserve are likely to be limiting factors for all-electric vehicles
• Assumed that autonomy required for business case to be positive although investment may be required in initial piloted trials
• Assumed volume will require centrally managed UTM although investment may be required in initial trials with individually commanded vehicles
• Automated pre-flight inspection required if pre-flight inspection mandated.

Security

• Current airport style security would render the business model unviable because of the significant negative impact on cost and total journey time
• Alternative approaches that deliver similar outcomes would need to be developed
• Cyber protection of aircraft control essential but judged to be less challenging than in point-to-point Around City case.

Legislation & regulation

• Since new technologies and configurations will need to be certificated, there will be significant challenges
• High density operations for into city usage will present significant challenges for UTM operation

Social acceptance

• The willingness to travel in autonomous air vehicles will be an enormous hurdle to overcome for the long-term.

ATM

• For a viable scale of market, autonomous vehicles and UTM will be required
• Inevitable initial trials are likely to commence using pilots with semi-autonomous stepping stones to autonomy and UTM.

Competition

• Depends heavily on the total journey time benefit versus cost when compared to other modes of transport.

Environmental impact

• Use over populated areas will be heavily dependant upon the level and nature of noise generated.

Manufacturing

• It is anticipated that high volumes will be met by suppliers accustomed to high volume sectors such as automotive.

Challenge of constraints for Into City case

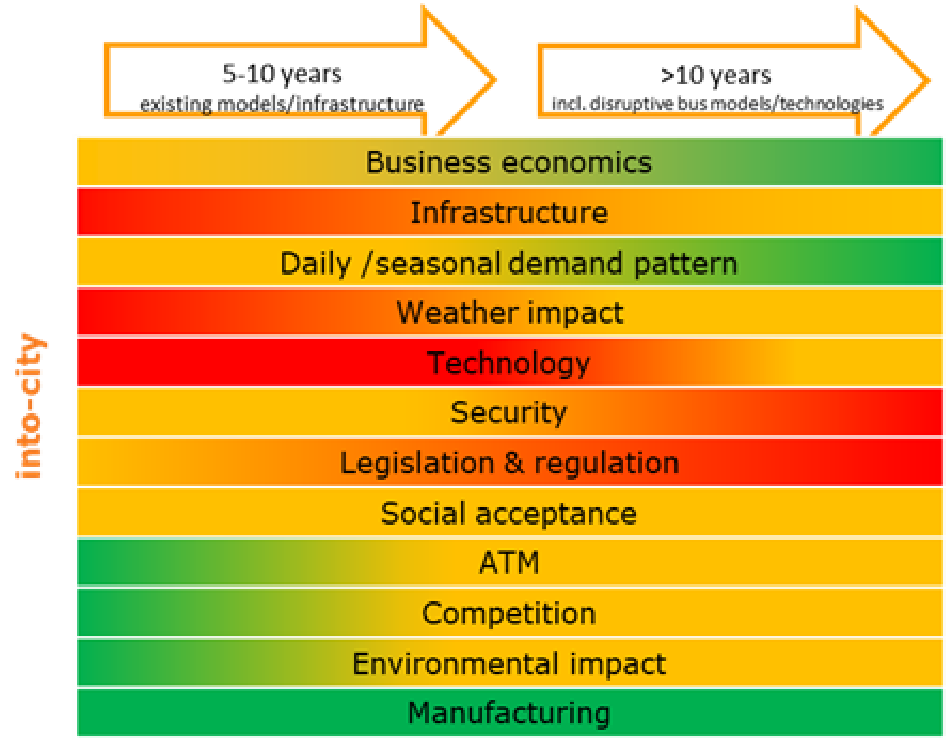

Figure 6

Assumptions

• Assumed public service operated in dense corridors e.g. airport to city centre hub.

Business economics

• Viability could rely on confidence of becoming autonomous but less so than in Around City use case
• Only economic at scale and high utilisation rate
• Not dependant on high number of landing points Including CAM.

Infrastructure

• Will require low number of hubs with significant infrastructure for operations, vehicle support, charging/ fuelling facilities.

Daily/seasonal demand pattern

• Very high one-way demand at peak times requiring high number of non-revenue flights to re-position aircraft
• Seasonal demand likely to mean some of fleet inactive off-season or redeployed in counter-seasonal regions.

Weather impact

• Lightweight and relatively low power margin leads to high impact of wind turbulence. Over time, the development of larger vehicles will have a positive impact
• Automation will have a positive impact in the long term.

Technology

• Assumed all-electric is required for acceptability into urban environment
• Power margin or energy reserve are likely to be limiting factors for all-electric vehicles
• Assumed that autonomy required for business case to be positive although investment may be required in initial piloted trials
• Assumed volume will require centrally managed UTM although investment may be required in initial trials with individually commanded vehicles
• Automated pre-flight inspection required if pre-flight inspection mandated.

Security

• Current airport style security would render the business model unviable because of the significant negative impact on cost and total journey time
• Alternative approaches that deliver similar outcomes would need to be developed
• Cyber protection of aircraft control essential but judged to be less challenging than in point-to-point Around City case.

Legislation & regulation

• Since new technologies and configurations will need to be certificated, there will be significant challenges
• High density operations for into city usage will present significant challenges for UTM operation. The use of corridors and early implementation with piloted vehicles is expected to reduce the short-term challenge.

Social acceptance

• The willingness to travel in autonomous air vehicles will be an enormous hurdle to overcome.

ATM

• For a viable scale of market, autonomous vehicles and UTM will be required
• Inevitable initial trials are likely to commence using pilots with semi autonomous stepping stones to autonomy and UTM.

Competition

• Depends heavily on the total journey time benefit versus cost compared to other modes of transport. Investment in fast surface and sub-surface mass-transit systems could present significant competition.

Environmental impact

• Use over populated areas will be heavily dependant upon the level and nature of noise generated. As traffic increases there are lightly to be challenges made on the energy use of flight versus terrestrial transport.

Manufacturing

• It is anticipated that high volumes will be met by suppliers accustomed to high volume sectors such as automotive.

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Contributors

The findings are those of the ADS UAM Group Market Workstream which includes individuals from Achieving the Difference LLP (workstream lead and author), ADS Group, Aerospace Technology Institute, Atkins, Consortiq, D5 Aviation, Faradair Aerospace, Leonardo Helicopters, Rolls-Royce, Swanson Aviation and Williams Advanced Engineering.