Enhancing Urban Air Mobility Integration in Cargo Transportation through Tiltrotor Technology

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ABSTRACT

The burgeoning field of Urban Air Mobility (UAM) promises transformative solutions to urban transportation challenges, with the potential to revolutionize cargo logistics in metropolitan areas. This research investigates the role of tiltrotor technology as a pivotal enabler of seamless UAM integration for efficient cargo transportation within urban environments. The study delves into the existing challenges within UAM, such as infrastructure limitations and the need for adaptable aerial vehicles that can navigate confined spaces while maintaining payload capacity. Tiltrotor Unmanned Aerial Vehicles (UAVs) are examined as a solution to these challenges due to their unique capabilities, combining vertical takeoff and landing (VTOL) with efficient forward flight. This research evaluates the potential of tiltrotor UAVs for urban cargo transportation, focusing on their operational efficiency, safety, and economic viability. Furthermore, the study explores the potential impact of tiltrotor technology on urban cargo logistics, considering factors such as reduced congestion, shorter delivery times, and environmentally sustainable operations. Real-world case studies and practical implementation strategies are discussed, shedding light on the importance of integration of tiltrotor UAVs into existing cargo transportation networks.

The findings of this research underscore the transformative potential of tiltrotor technology in enhancing UAM for cargo transportation within urban areas. The study contributes valuable insights to the ongoing discourse on UAM integration and lays the groundwork for future developments in autonomous aerial cargo delivery systems.

Keywords: *Urban Air Mobility (UAM), Tiltrotor Technology, Cargo Logistics, Metropolitan Areas Aerial Vehicles, Vertical Takeoff And Landing (VTOL), Safety, Delivery Times, Autonomous Aerial Cargo Delivery*

INTRODUCTION

In an ever-changing world, the dynamics of urban transportation are undergoing a fundamental transformation, reshaping the movement of both people and goods within cities. The rapid urbanization and population growth we're witnessing have given rise to new challenges in meeting the escalating demands for cargo transportation within densely populated urban areas. Conventional ground-based transportation systems, often hampered by traffic congestion and infrastructure limitations, are proving increasingly inadequate to support the burgeoning logistical needs of modern cities. These challenges have underscored the necessity for innovative transportation solutions that are efficient, sustainable, and capable of navigating the intricacies of urban environments.

Companies like Uber have demonstrated their potential in meeting customers' demands for passenger transportation. They operate efficiently, allowing customers to order rides and make payments through their smartphones. Another division of uber company known as uber elevate focused specifically Uber on the development and implementation of Urban Air Mobility (UAM) solutions, such as electric vertical takeoff and landing (eVTOL) aircraft for passenger and cargo transportation within urban areas. While it is part of the larger Uber organization, Uber Elevate has a distinct focus on the aerial mobility sector and aims to provide on-demand air transportation services as an extension of Uber's existing ground-based ride-sharing platform. They have defined optimal aircraft performance standards for UAM and emphasize the importance of battery technology advancements. Uber Elevate has identified various challenges, including safety, infrastructure, noise, emissions, and public perception, and is working to bring together stakeholders from different sectors, including manufacturers, regulators, and the public, to accelerate UAM development. They are also partnering with aircraft manufacturers and promoting open-source collaboration to facilitate UAM's growth and ensure safety (Straubinger et al., 2020). This involvement now serves as a role model for the air transportation industry.

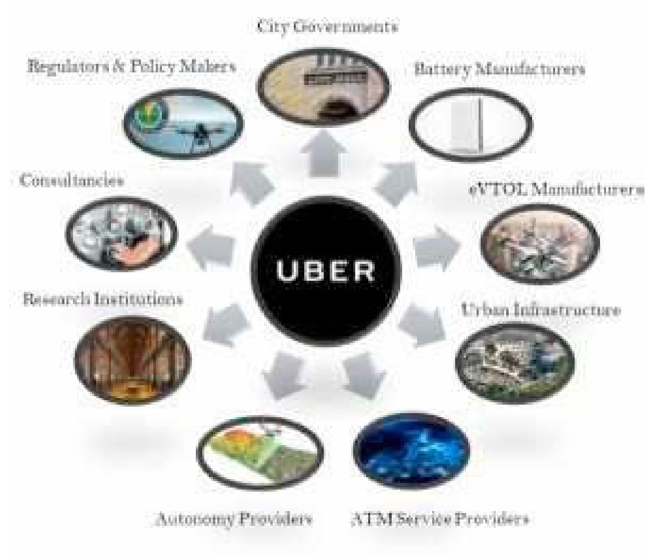

Fig 1. Uber Elevate Network in Creating Urban Air Mobility(Roma, 2020)

Moreover, various approaches to achieving sustainable transportation have been adopted. For instance, in some advanced cities, there has been notable progress in using couriers on bikes or motorcycles to deliver items to different locations within stipulated timeframes. The primary goal of using bikes as a mode of transportation is to bypass traffic and meet delivery expectations. However, this solution has its limitations, including factors such as the reliability of the rider, traffic congestion, and unforeseen incidents or accidents that can affect delivery efficiency.

While new technology has ignited fresh interest and investment in the market, aircraft companies, government organizations, universities, and individual researchers are actively engaged in urban mobility projects. Their collective aim is to transform urban transportation into a tangible reality in the near future. Significant technological development and the increasing importance of comfort (CZECH, 2018) have made meeting the demands of urban transportation a top priority for many, with a focus on providing stress-free, safe, reliable, and time-efficient means of getting around.

We have seen initiatives like the one conducted by (Bansal et al., 2016), who conducted an online survey to understand people's opinions on the adoption of new smart car technology, known as autonomous vehicles. Additionally, Anuj Puri (Puri, 2016) conducted a survey on the use of UAVs for traffic surveillance, with a focus on their application in traffic management. He proposed the use of UAVs as a secondary perspective to provide real-time information for traffic surveillance, road conditions, and emergency response.

NASA's research centers are also making dedicated efforts towards the development of sustainable transportation. Various methods of VTOL aircraft design and parts of the design process followed by NASA have been published by

Despite transportation still presenting significant challenges, the utilization of urban airspace has emerged as one of the proposed solutions. This concept has been in development for several years and it's important to note that pinpointing the exact inception year of this research and intention is challenging because it has evolved over time in tandem with advancements in technology and infrastructure. In recent years, it has gained prominence under the name "Urban Air Mobility" (UAM). UAM envisions a new era of aerial transportation within cities, significantly harnessing urban airspace. It relies on the concept of electric vertical takeoff and landing (eVTOL) aircraft to provide on-demand, point-to-point air transportation services within urban and suburban areas. Supporters of Urban Air Mobility (UAM) contend that electric aircraft represent a pivotal technological advancement, offering solutions to numerous challenges encountered by helicopter and small aircraft air taxi services. These electric aircraft are anticipated to surpass conventionally powered counterparts in short-range missions, thanks to their lower power-to-weight ratio, enhanced overall efficiency, and increased integration potential within the airframe(Parker D. Vascik, 2017). Furthermore, distributed electric propulsion technologies are being considered as a way to reduce aircraft noise levels and address concerns regarding community acceptance. Additionally, there is a theoretical belief that fully electric aircraft might lower direct operating costs by as much as 20% when compared to traditional aircraft. This cost reduction is attributed to improved overall efficiency and decreased maintenance expenses (Parker D. Vascik, 2017)

The use of electricity as an alternative or supplementary power source for aircraft is not a recent concept. The initial proposals for electrical propulsion systems in aviation date back to 1943, with the aim of harnessing the advantages of distributed propellers and electric motors. In the period spanning from 1983 to 2003, NASA collaborated with AeroVironment to develop and operate four experimental flight test vehicles. These endeavors were dedicated to advancing the core technologies essential for fully electric solar-powered flight. The four test vehicles, named Pathfinder, Pathfinder-Plus, Centurion, and Helios, were unmanned systems employed by NASA to refine concepts related to electric propulsion and distributed electric propulsion. These projects represented significant milestones in the development of electric propulsion technologies for aviation.(Parker D. Vascik, 2017). In addition to these aerospace-specific innovations, progress in electric engine power density and battery technologies has been primarily driven by the automotive and heavy industries. The production scale of hybrid and fully electric cars is significantly larger than what electric aviation is expected to achieve, resulting in substantial resources devoted to advancing this technology.(Parker D. Vascik, 2017)

Nevertheless, despite the developments seen in manned solar vehicles and high-altitude, long-duration solar Unmanned Aircraft Systems (UAS), it is unlikely that cost-effective fully electric regional or long-haul commercial aircraft will become feasible in the near future due to limitations in energy storage capacity. However, at the smaller end of the passenger and payload spectrum, electric propulsion, integration, and storage technologies have progressed to the point where they could potentially support economically viable short-range aircraft suitable for on-demand mobility (Parker D. Vascik, 2017). Below are the manufacturers proposing to develop and produce On-demand Mobility (ODM) aircraft.

Manufacturer	Vehicle Type
Aero Electric Aircraft Company	Solar-electric trainer aircraft
AeroMobil	Roadable, conventionally powered aircraft
Airbus A^3	Electric VTOL multicopter
Aurora Flight Sciences	Electric VTOL aircraft
Carter Aviation	Conventionally powered VTOL aircraft
EHang	Electric VTOL multicopter
Elytron	Conventionally powered VTOL aircraft
Eviation	Hybrid Al-Air+LiPo aircraft
Evolo	Electric or hybrid VTOL multicopter
Joby Aviation	Electric VTOL aircraft
Kitty Hawk	unknown
Lilium Aviation	Electric VTOL aircraft
Moller International	Conventionally powered VTOL aircraft
Mooney International	Electric trainer aircraft
Terrafugia	Roadable, conventionally powered aircraft
XTI Aviation	Conventionally powered VTOL aircraft
Zee.Aero	Electric VTOL aircraft

Fig 2. On-demand mobility aircraft manufacturers (Parker D. Vascik, 2017)

The goal of Urban Air Mobility (UAM) is to address urban congestion challenges and provide faster, more efficient, and environmentally friendly transportation options within cities. Some advanced countries have already initiated its implementation, considering it a step towards building smart cities. However, fully realizing the potential of UAM requires innovative approaches beyond conventional fixed-wing aircraft and helicopters. This is where tiltrotor Unmanned Aerial Vehicles (UAVs) come into play—a cutting-edge technology that combines vertical takeoff and landing (VTOL) capabilities with efficient fixed-wing flight, offering a unique solution for seamless cargo transportation in urban environments.

This research embarks on a journey to explore the groundbreaking possibilities presented by tiltrotor UAVs in revolutionizing urban cargo transportation. By harnessing the inherent advantages of tiltrotor technology, such as VTOL, hover capabilities, and efficient forward flight, our aim is to usher in a new era of cargo logistics marked by agility, speed, and sustainability. The significance of this research lies in its potential to reshape how we perceive cargo transportation in urban settings. Through an exhaustive review, this study seeks to illuminate the feasibility and advantages of integrating tiltrotor UAVs into urban cargo transportation networks. It endeavors to address critical questions concerning operational efficiency, safety, and economic viability—all while aligning with broader goals of achieving sustainable and efficient urban transportation systems. In the following pages, we delve into the literature review, focusing on past and present research on UAM and the advancements in this emerging technology. We also explore the intricacies of tiltrotor technology and its potential applications in the context of urban cargo transportation. By examining the current landscape, identifying challenges, and proposing innovative solutions, this research aims to provide a comprehensive framework for the seamless integration of tiltrotor UAVs into urban air mobility for cargo transportation. Through meticulous case studies and the lessons learned from the literature review, we aim to contribute to the realization of a future where cargo logistics in urban areas are transformed into a seamless, efficient, and sustainable operation.

The following section presents the hierarchy of relevant transportation technology.

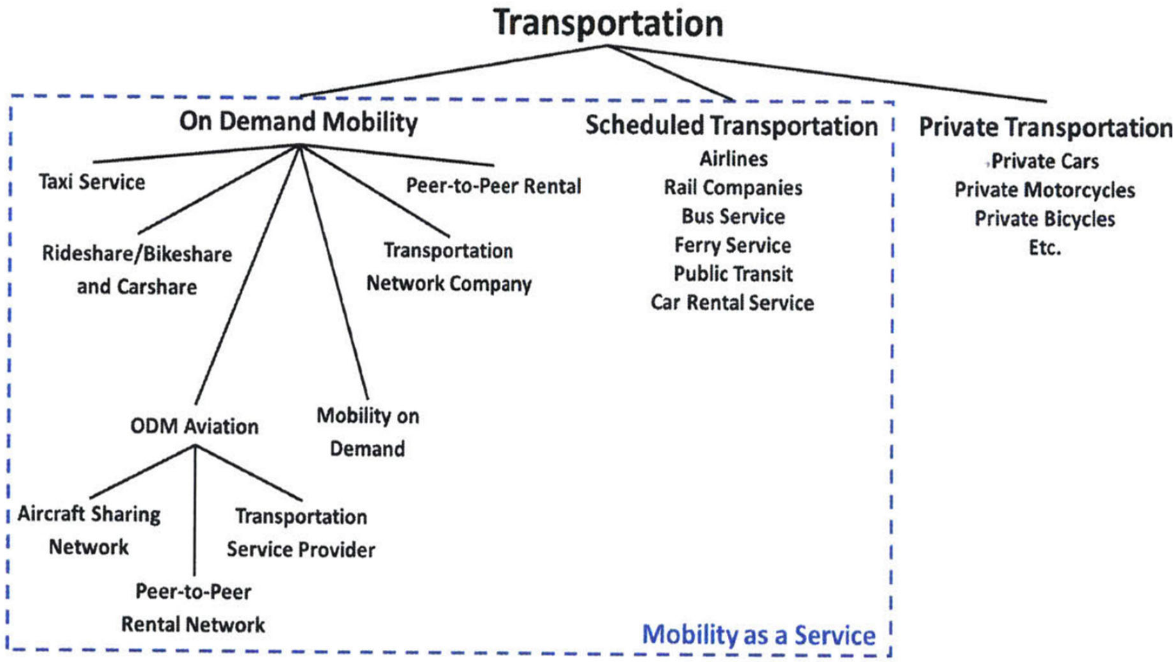

Fig 3. Hierarchy of new transportation technology(Parker D. Vascik, 2017)

The timely and efficient delivery of goods is crucial for both businesses and consumers. Urban Air Mobility (UAM) technologies hold the promise of alleviating urban congestion and reducing delivery times. In this context, Unmanned Aerial Vehicles (UAVs) emerge as a disruptive force capable of reshaping the cargo logistics landscape. However, the widespread implementation of UAM faces numerous technical, regulatory, and infrastructure challenges that demand attention. Many of these challenges have been thoroughly examined in various literature reviews, and sustainable solutions have been proposed to address them.

LITERATURE REVIEW AND PROGRESS MADE.

COMBINED REVIEW ON URBAN AIR MOBILITY

Systems-Level Analysis of On Demand Mobility for Aviation (Parker D. Vascik, 2017)

(Parker D. Vascik, 2017) discusses a thesis that aims to assess the technology maturity of On-demand Mobility services with the goal of enhancing scalability and profitability within the aviation industry while ensuring customer satisfaction. The writer's focus is on the utilization of unmanned aerial vehicles (UAVs) and other aircraft to provide on-demand services to individuals. It's emphasized that more than 15 companies, including NASA, are actively developing and building on-demand technologies. Importantly, the thesis takes a comprehensive approach by anticipating aircraft-based On-Demand Mobility (ODM) services without getting into the intricacies of technology development. The primary objective is to identify operational constraints and evaluate potential solutions in both the short and long term. The analysis adopts a systems-level perspective, considering various interdisciplinary factors that may impact ODM services. These factors encompass restrictions imposed on ODM networks due to air traffic control, integration with ground infrastructure, load balancing within the network, interactions with unmanned aircraft, community noise concerns, and more.

The research questions are structured into three key approaches:

1. Constraints: These encompass various critical factors, such as technological, operational, regulatory, business, or system interfaces, that could potentially hinder or restrict the implementation of ODM Aviation within the United States.

2. Externalities: These external factors may emerge as a result of the widespread adoption of ODM Aviation networks in the United States. It's essential to examine the potential societal impacts stemming from this proliferation and how they might, in turn, shape the landscape of ODM Aviation.

3. Mitigation Strategies: This involves identifying viable technology and policy options, both in the short and long term, to address the limitations and negative consequences associated with the implementation of ODM Aviation in the United States.

The author has developed a comprehensive system to visualize the concept of ODM (On-Demand Mobility) aviation and to identify potential implementation challenges in the United States. The methodology employed for the system design was straightforward and rooted in a deep understanding of the subject. The system focused on specific U.S. states as case studies and conducted a thorough analysis of their market structure concerning ODM aviation. Factors considered included commuting patterns, income levels, household valuations, and the presence of existing charter services.

Subsequently, the system outlined a reference mission, aligning it with each state's specific aviation requirements. A concept of operation was then delineated, providing a detailed overview of how customers would place orders and use the services to reach their destinations. Finally, a multi-domain analysis was conducted to offer a holistic perspective on the potential operational challenges that an ODM aviation network might encounter. This approach allowed for a comprehensive examination of ODM aviation's feasibility and potential obstacles within a specific U.S context. The overall research highlights the market structure and market demand of ODM aviation. The author also raises concerns that if urban air mobility or on-demand mobility aviation is implemented without diligent and intentional planning, it could result in numerous negative externalities. This may disrupt the equilibrium between cities, unveil privacy concerns due to aircraft flying at low altitudes generating noise unacceptable to society. Moreover, implementing aviation in the wrong way might pose security threats, allowing various aircraft to fly without authorization in a particular airspace, potentially providing opportunities for malicious acts.

Safety When Flying Unmanned Aerial Vehicles At Transport Infrastructure Facilities (Shvetsova & Shvetsov, 2021)

In 2021, (Shvetsova & Shvetsov, 2021) analyzes a way to solve the ban on unmanned aerial vehicles over transport facilities in many countries, especially airports. The ban on unmanned aerial vehicles over airports is due to the potential collision risks during the takeoff and landing of aircraft. Additionally, managing unmanned aerial vehicles would impose an additional workload on airspace management agencies.

In this study, factors for the safe use of unmanned aerial vehicles at transport infrastructure facilities are formulated. The study considers these factors and introduces a simple air tunnel to facilitate the movement of unmanned aerial vehicles. This air tunnel is robustly constructed to shield unmanned aerial vehicles from pedestrian pathways. The method is implemented using sheet cellular polycarbonate, optical fiber, aluminum n-shaped profiles, and aluminum profiled sheets for the creation of the air tunnel, ensuring both strength and lightness of the air tunnel. The author also emphasizes the operating movement of the UAVs inside the air tunnel to ensure the safe movement of UAVs and the items they are transporting. Rules are established for the movement from one UAV to another to avoid collisions. Practical tests of the materials used in creating the air tunnel were conducted, yielding various results. The results are as follows: the material did not affect the quality level of the radio signal from the UAV to the operator, and it also did not affect the quality of the GPS signal used for UAV navigation. The material's strength was also confirmed through impact testing, where a 3kg metal disk was dropped onto the material, resulting in damage to the metal disk but not affecting the integrity of the air tunnel. This suggests that items must be packaged securely to withstand potential incidents and that UAVs must also be protected when they come into contact with the sides of the air tunnel. The author provides an alternative way to avoid this damage by equipping the propellers of the UAVs with protective covers. However, this solution has drawbacks related to the implementation of the air tunnel. It would require a substantial investment rather than utilizing existing airspace and effective mission planning of UAVs from one location to another to avoid collisions. The implementation of the air tunnel is shown below.

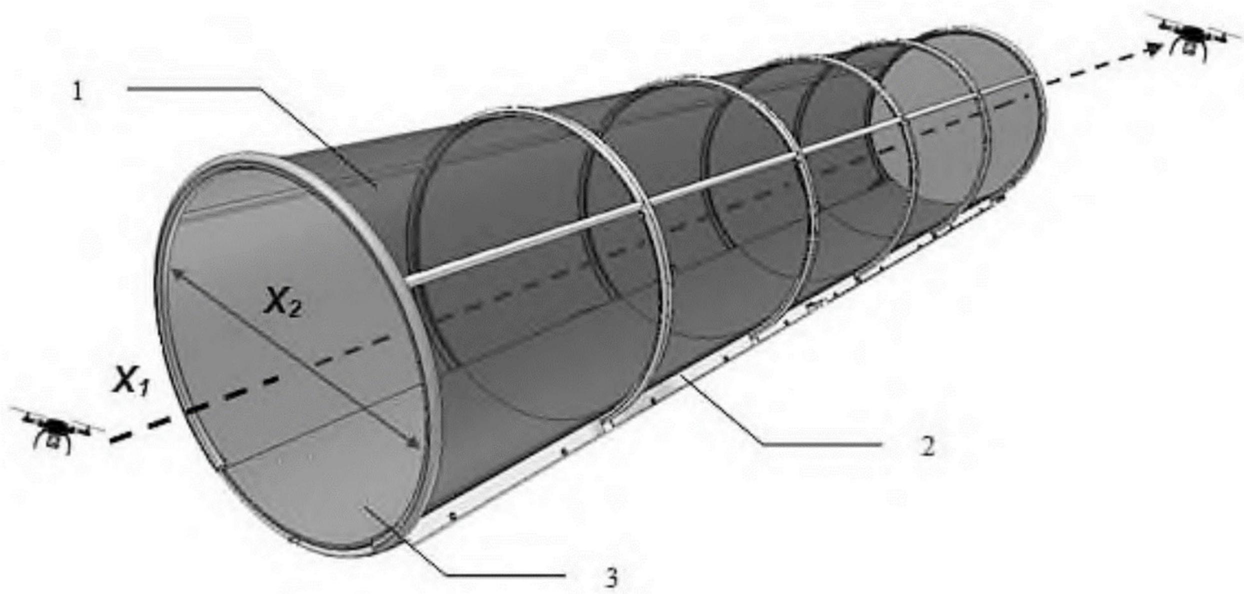

Fig 4. Designed Air Tunnel (Shvetsova & Shvetsov, 2021)

Final Report Urban Air Mobility (UAM) Market Study (NASA, 2018)

The Booz Allen Team (NASA, 2018) conducted a study on Urban Air Mobility (UAM) in 2018, focusing on three potential markets: Airport Shuttle, Air Taxi, and Air Ambulance. They found that the Airport Shuttle and Air Taxi markets had substantial potential, with a total available market value of $500 billion in the U.S. The study identified challenges and barriers, which can be categorized based on their potential mitigation through technology and market maturity. Challenges include high service costs, weather impacts, high-density operations, battery limitations, noise and environmental concerns, infrastructure constraints, competition from existing transportation modes, and public safety and perception concerns. Some challenges can be addressed through technological advancements and market maturation, while others require long-term solutions.

The team adopted four approaches to understand the urban air mobility ecosystem, and they are as follows:

1. Scoping: Identifying missions that can be served with vertical take-off and landing (VTOL) vehicles.
2. Initial assessment: Focusing on three market analyses which center on preliminary market analysis and evaluating barriers.
3. Interim Assessment: Conducting a comprehensive analysis of the initial assessment.
4. Final assessment: Documenting lessons learned and recommendations.

In summary, the study assesses the potential of UAM markets, outlines existing challenges, and suggests strategies for overcoming them to realize the full potential of UAM in the transportation sector. Moreover, there's a compelling case for conducting additional research aimed at providing the public with a more realistic grasp of UAM travel. This could be achieved through flight simulations or pilot programs, offering respondents firsthand experience and insights. Additionally, exploring the influence of urban congestion on UAM perceptions could yield valuable insights, considering that commute distances and attitudes toward congestion vary among respondents. The study has also shed light on the complexities of weather impacts on UAM operations. While it's clear that Instrument Flight Rules (IFR) conditions can significantly affect piloted Visual Flight Rules (VFR) operations, the impact becomes minimal for fully automated vehicles equipped with sensors for IFR flight. These findings underscore the need for future studies to delve into specific case examples to accurately capture weather-related barriers and their implications. Furthermore, the assumptions made about technology, operations, and market scenarios throughout this study highlight the importance of regularly updating these assumptions to align with real-world developments. Future studies should closely monitor technology infusion trends and sustainability factors.

Factors Affecting the Adoption and Use Of Urban Air Mobility (Al Haddad et al., 2020)

A transportation research was also conducted in the year 2020 which focused on the factors affecting the adoption and use of urban air mobility(Al Haddad et al., 2020). This paper conducted an online stated preference study involving 221 participants worldwide, including a subset of 97 Munich residents, to evaluate the acceptance and adoption of urban air mobility (UAM). By drawing upon factors commonly associated with technology and automation acceptance, particularly in the context of autonomous vehicles, the study aimed to generate hypotheses regarding this emerging mobility service. The result of the survey provides valuable insights for policymakers and industry stakeholders, and those insights are as follows:

- Safety Concerns: Policymakers should consider regulations focusing on human control of UAM.
- Environmental Concerns: It is necessary for policymakers to regulate environmental hazards produced by the UAVs. This includes regulating allowable noise levels and flying altitudes of the vehicles to address community acceptance among both users and non-users of urban air mobility.

For industry stakeholders, the survey proposed insights for service attributes and social demographics. The service attributes include meeting customer demands such as time and cost to attract the public, while the social demographic attributes emphasize targeting various backgrounds and cultural beliefs based on their specific needs.

An Overview of Current Research And Developments In Urban Air Mobility – Setting The Scene For UAM Introduction (Straubinger et al., 2020)

This paper aims to provide a comprehensive overview of various research areas within the emerging field of Urban Air Mobility (UAM). It seeks to address questions and challenges related to the implementation of UAM, which has the potential to revolutionize passenger transport within and between urban areas. It covers a wide range of topics within the UAM research community, including aircraft requirements and classifications for passenger transport within and between cities. It also delves into potential obstacles to the introduction of UAM, including issues related to certification, policy, traffic management, and ground infrastructure. Additionally, it provides insight into past research and human development in building a standard smart city known as UAM.

The regulatory section discusses certification, past and current research and development, and expected methods of implementation. It addresses the significant challenges associated with ensuring the safety and regulatory compliance of urban air mobility (UAM) operations. Certification standards and regulations are being developed by aviation authorities such as the European Aviation Safety Agency (EASA) and the US Federal Aviation Administration (FAA) to govern UAM. EASA's proposed regulations for "Enhanced VTOL" aircraft, intended for urban air transport, are discussed. These regulations set safety standards similar to those applied to smaller commercial aircraft, limiting the number of passengers to five and establishing a maximum take-off mass. Moreover, they require the design of aircraft to ensure continued safe flight and landing even in the event of a critical propulsion system failure.

The certification section also addresses the introduction of regulations related to airspace for UAM. It mentions the development of airspace types, modalities, and access based on the U-Space concept, which supports unmanned aerial systems' operations. However, it highlights that implementing this concept may add more work for airspace management agencies. Furthermore, it emphasizes that certification extends beyond aircraft to include various aspects, including training, landing areas (UAM pads), maintenance regulations, operating organization requirements, air traffic management (ATM), and air navigation services (ANS). Databases on obstacles and terrain, security regulations for passengers and personnel, and addressing externalities such as noise, air pollution, and congestion are also essential.

The paper suggests that UAM might face regulatory interventions similar to those observed in other transport sectors due to factors like natural monopolies, externalities, and information asymmetry. While predicting regulatory responses is challenging, market-regulating policies could be introduced to address these concerns in the UAM market.

The Ground Infrastructure section discusses the critical aspects related to the infrastructure needed for urban air mobility (UAM) operations, with a specific focus on the ground infrastructure requirements for take-off and landing, referred to as vertiports or vertistops. The paper highlights the lack of extensive research on UAM ground infrastructure despite its importance, especially during the high-risk flight phases of take-off and landing, as well as for ensuring vehicle throughput and accessibility. Various options for the placement of UAM ground infrastructure are discussed, including rooftops, barges over water, inside highway cloverleafs, and on top of existing ground-transport infrastructure. The authors mention that current research in this area references existing helicopter infrastructure regulations and adapts them to accommodate different UAM vehicle designs. Additionally, the possibility of considering deviations from safety regulations for electric vertical take-off and landing (eVTOL) vehicles using exclusively electric propulsion and energy storage is raised.

The placement of UAM stations is another aspect discussed, with the paper noting the absence of empirical methods for station placement. Some studies consider factors such as population density, job density, median income, noise levels, and accessibility to major transport hubs when identifying suitable station positions. The importance of station accessibility to existing transportation modes, especially to airports or major train stations, is emphasized. However, the paper points out a lack of consensus among researchers and experts regarding the importance of various factors in station placement. Additionally, there is limited research on mode choice regarding access and egress to UAM stations, also known as the first or last mile, making it unclear what facilities UAM stations must provide to ensure a seamless and attractive travel experience for passengers.

In summary, the paper addresses the complexities and considerations related to UAM ground infrastructure, including vertiport placement, space requirements, and factors influencing station location and accessibility. It underscores the need for further research and consensus-building in this crucial aspect of UAM development.

Decentralized Control Synthesis For Air Traffic Management In Urban Air Mobility (Bharadwaj et al., 2021)

The paper focuses on developing a decentralized and hierarchical UAM Air Traffic Management (ATM) architecture capable of handling high traffic densities while providing theoretical guarantees of correctness regarding safety specifications. Additionally, it introduces a contract-based approach to ensure the safety of UAM operations based on user-provided specifications. In this architecture, control authority is divided among vertihubs, each responsible for managing UAM vehicles in its local airspace. Furthermore, each vertihub contains vertiports, responsible for UAM vehicle takeoffs and landings. This architecture ensures scalability and robustness, even in the event of the failure of individual vertihubs or vertiports.

The vertiport is designed to operate from one vertiport to another within a particular region, and the operational mode is illustrated below:

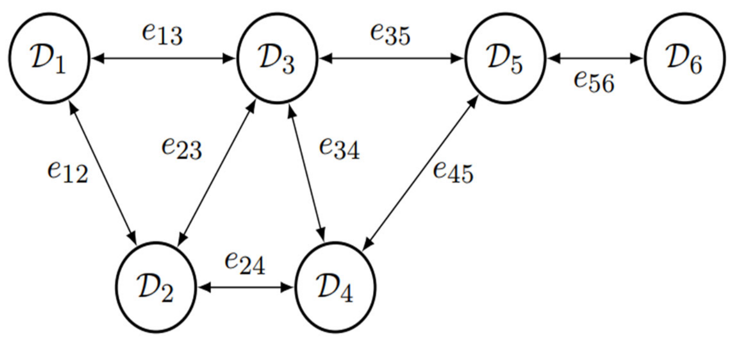

Fig 5. Movement of UAVs Within A Vertiport (Bharadwaj et al., 2021)

This mode of operation facilitates the easy management of UAVs in a specific region, ensuring smooth movement from one vertiport to another with comprehensive monitoring of operations within that region.

The author also models the vertihub, which is a regional model. A vertihub comprises many vertiports, and accessing one vertihub from another requires approval. This can be likened to accessing the airspace of a particular region. An intersection region exists between two vertihubs, and controllers from each vertihub grant approval. A vertihub is responsible for managing requests by UAM vehicles (referred to as vehicles) to either land at or take off from a desired vertiport in its region or pass through to a neighboring region. Each vertiport within a vertihub is in charge of facilitating takeoffs and landings at its landing pads. The author employs mathematical set theory to provide this solution.

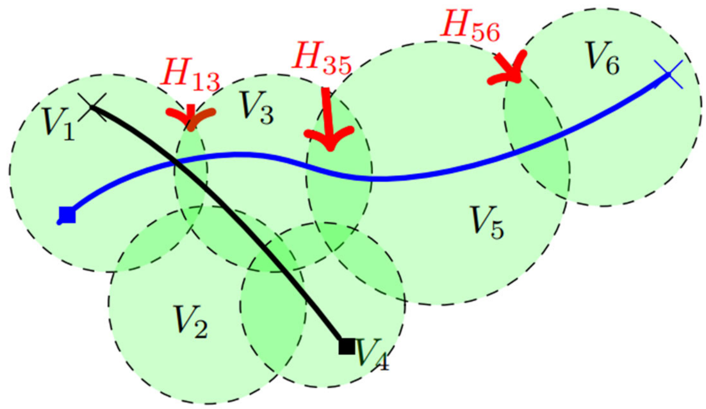

Fig 6. Vertihub Design (Bharadwaj et al., 2021)

Since the control of vertihubs and vertiports is decentralized, not under the control of a central body, a controller is designed for the operation of the vertiport and vertihub. This is done to ensure the safety of the overall system. The "Vertihub controller" refers to the controller responsible for managing each vertihub (designated region) within the context of urban air mobility (UAM). It is modeled as a reactive system with specific characteristics and functionalities tailored to the needs of each vertihub. The system is designed in such a way that actions taken by one hub controller (e.g., directing vehicles to loiter) can impact the connected hub controllers. This interdependence necessitates the use of contracts between hubs to ensure that the entire UAM system behaves as desired, maintaining safety and efficiency across interconnected vertihubs.

A Traffic Demand Analysis Method for Urban Air Mobility (Bulusu et al., 2021)

This paper explores the potential of Urban Air Mobility (UAM) as a solution to address urban transportation challenges, with a specific focus on its role within the multi-modal travel paradigm. The central question it seeks to answer is, "What is the maximum number of people in a metropolitan region that can benefit from UAM?" To address this question, the authors develop a method based on traffic demand analysis, using the San Francisco Bay Area as a sample application. The paper also discusses how commuters can choose between uni-modal (e.g., road travel) and multi-modal (using vertiports for air travel) transportation options based on travel time and flexibility. The distribution of vertiports across a region significantly impacts travel time benefits and mode shift decisions. To determine the optimal number and location of vertiports in a metropolitan area, the authors employ k-means clustering to analyze their distribution. They then calculate travel times, estimate the number of commuters who would benefit, and assess capacity and cost justification criteria for various combinations of vertiports.

In essence, this paper aims to identify the maximum number of commuters who can benefit from UAM by optimizing the placement and number of vertiports, all while considering travel time advantages and mode shift preferences. It addresses key factors such as technology, operational efficiency, and infrastructure to provide valuable insights into the potential of UAM in urban transportation. The paper provides evidence supporting why UAM may become a lasting solution in the field of urban transportation (Bulusu et al., 2021).

Urban Air Mobility: Safety Challenges (Roma, 2020)

This paper addresses the issue of aviation safety, with a particular focus on the impact of flight crew errors on aircraft operations. It introduces the concept of aviation safety, as defined by ICAO, and proposes solutions based on accidents that have occurred in the aviation industry. The paper emphasizes the importance of understanding and mitigating flight crew errors, especially in the context of emerging technological trends in aviation, such as Urban Air Mobility (UAM). It highlights that the introduction of new technologies in aviation will present new safety challenges that must be comprehensively addressed through updated safety goals and principles of safety management. In essence, the paper underscores the critical role of addressing human errors to enhance safety in aviation, especially in the evolving landscape of UAM.

Designing Airspace for Urban Air Mobility: A Review of Concepts and Approaches (Bauranov & Rakas, 2021)

Due to numerous challenges hindering the integration of UAM technologies into existing airspace and urban operations, including increased operations, higher operational density, lower altitudes, and variations in performance among operators and air vehicles, this paper (Bauranov & Rakas, 2021) explores the design and management of urban airspace within the emerging field of urban air mobility (UAM) concepts. It reviews proposed airspace designs, identifies key factors influencing urban airspace, and assesses the strengths and weaknesses of different concepts. The study categorizes these influencing factors into safety-related, social, system, and aircraft factors. The analysis reveals that many airspace concepts prioritize safety and capacity while overlooking factors such as technological complexity, noise, and privacy. The paper highlights the trade-offs between structured and less structured airspace in terms of capacity, efficiency, and safety. Less structured airspace can offer greater capacity and route efficiency but demands advanced technologies for safety. Conversely, more restrictive airspace structures, such as lanes, accommodate less-equipped aircraft but may lead to delays.

The study examines how various major technology-driven countries have managed their airspace in the context of UAM technology integration. Additionally, it delves into Uber's approach to UAM, which relies on existing technologies and NASA's Unmanned Traffic Management (UTM) proposal. The study also engages in a discussion about the principles of designing urban airspace, with a particular emphasis on social acceptance. This emphasis aligns with Uber's strategic imperative, as the success of its UAM service depends on positive user acceptance. Below, we show one of the fore-runners of UAM, Embraer-X, and its unmanned traffic management (UTM) proposal for airspace integration.

Fig 7. Embraer-X (UTM) (Bauranov & Rakas, 2021)

The study concludes by recommending further research in areas such as risk assessment, data usage, new technologies, psychoacoustic effects of drone noise, community input and design, and the impact of ground infrastructure on urban planning. It emphasizes the need for a holistic approach to analyzing urban airspace, considering urban planning issues, public acceptance, and access inequalities in the context of UAM development.

Implementing Mitigations for Improving Societal Acceptance of Urban Air Mobility (Çetin et al., 2022)

This journal discusses the challenges and concerns associated with the rapid development of unmanned aerial vehicles (UAVs) or drones. UAVs are increasingly utilized across various sectors, including agriculture, search and rescue, photography, and delivery services. The expansion of drone operations into urban and suburban areas, as part of the concept of urban air mobility (UAM), has raised significant societal, safety, and environmental concerns.

The paper highlights that the growth of the drone industry has led to apprehensions among the public, largely due to the unfamiliarity with this technology. To address these concerns and enhance public acceptance, the journal presents the primary societal worries regarding drone operations, as identified through public surveys. It further proposes a list of mitigation measures aimed at alleviating these concerns. Below is a prioritized list of the top 10 mitigation measures for implementing drones.

M1	**Limit minimum altitude** The concerns addressed: Noise impact, impacts on animals and flora, visual pollution, safety concerns, security concerns, loss of privacy/intrusion
M2	**Establish no-fly zones for drones** The concerns addressed: Noise impact, impacts on animals and flora, visual pollution, safety concerns, security concerns, loss of privacy/intrusion
M3	**Identify a strategic location for vertiports** The concerns addressed: Noise impact, emissions impact, impacts on animals and flora, visual pollution, safety concerns, security concerns
M4	**Public knowledge about drone technology and operations** The concerns addressed: Loss of privacy/intrusion, lack of transparency, competency, economic viability, demand
M5	**Avoid/limit hovering drone flights** The concerns addressed: Noise impact, impacts on animals and flora, visual pollution, loss of privacy/intrusion
M6	**Promote the use of renewable energy sources to recharge batteries. Use of SAF for hybrid drones** The concerns addressed: Emissions impact, recycling, impact of climate change, economic viability, demand
M7	**Ensure proper maintenance processes and controls for batteries to extend their life cycle** The concerns addressed: Emissions impact, recycling, impact of climate change, safety concerns
M8	**Work with eco-friendly drones(re-cycling parts)** The concerns addressed: Emissions impact, recycling, impact of climate change, economic viability
M9	**Ensure that the cost of drone services commensurate with the value of the activity** The concerns addressed: Cost of services, competency, jobs, economic viability
M10	**Developing a risk and safety culture in the drone industry** The concerns addressed: Competency, jobs, economic viability, demand

Fig 8. Prioritized Top 10 Mitigation Measures (Çetin et al., 2022)

Urban Air Mobility: Opportunities and Obstacles (Cohen & Shaheen, 2021)

The paper offers a comprehensive overview of the concept of Urban Air Mobility, including its potential use cases, challenges, recent developments, and the role of research and regulation in shaping its future. Additionally, it examines the impact of the COVID-19 pandemic on potential applications of UAM. The paper also delves into the specific areas of research that require focused attention in the context of UAM.

Are We Ready to Weather Urban Air Mobility (UAM)? (Reiche et al., 2019)

The paper provides an initial assessment of how historical weather conditions and public perception could impact UAM operations. It introduces the concept of Urban Air Mobility (UAM), which is a transportation system designed for moving passengers and air cargo within urban areas using various types of aerial vehicles. The paper explains the range of UAM operations, including piloted and autonomous flights, small package delivery, and urban unmanned aerial systems (UAS). It also highlights that pilot projects have been initiated in cities like Dubai, with plans for further implementation in Dallas and Los Angeles. The paper emphasizes that while UAM is advancing rapidly, limited research has been conducted on the potential impacts of weather conditions on the safety, cost, and efficiency of UAM operations and vehicles. The author's research focuses on two key areas:

1. Climatology Analysis: A comprehensive seasonal and diurnal climatology is generated based on historical weather observations across anticipated UAM operational altitudes (from the surface to 5000 feet above ground level) in ten focus urban areas in the United States. This analysis helps characterize challenging weather conditions that UAM operations may encounter.

2. Regional Variability: The study also considers regional variability in weather conditions and potential barriers, recognizing that weather conditions can vary significantly from one urban area to another.

Urban Air Mobility: Systematic Review of Scientific Publications and Regulations for Vertiport Design and Operations (Schweiger & Preis, 2022)

The paper discusses the emergence of Urban Air Mobility (UAM) and its potential to transform urban transportation through innovative electric aircraft designs. It highlights the critical role of efficient ground infrastructure in enabling safe UAM operations within urban environments. However, due to its novelty, research on UAM ground infrastructure has been fragmented.

The primary objective of the paper is to systematically select, categorize, and summarize existing literature related to UAM ground infrastructure. This effort aims to contribute to the harmonization of initiatives by industry, research, and regulatory authorities. The authors employed a document term matrix approach to identify 49 scientific publications listed in Scopus from 2016 to 2021. These publications cover various aspects of UAM ground infrastructure, including airspace operation, design, location, network, throughput and capacity, ground operations, cost, safety, regulation, weather, noise, and security. The paper highlights that topics related to cost and beyond seem to be under-represented in the literature but are crucial for addressing current developments and challenges in UAM. It places a particular emphasis on vertiport design and its significance within the UAM ecosystem. Vertiports are identified as critical elements in the UAM landscape, especially concerning the management of limited spatial resources. They play a pivotal role in determining the capacity and performance of UAM networks. The paper raises pertinent questions regarding how vertiports will accommodate various VTOL aircraft types and multiple UAM service providers. It also explores how vertiports can contribute to reducing ground traffic congestion. Furthermore, the paper delves into the current state of vertiport design and operations, considering them more as visionary concepts than practical implementations. It also discusses the potential impact of weather and environmental constraints on UAM and vertiport operational hours, recognizing their significance in shaping the future of UAM.

Overall, the paper provides a comprehensive overview of the various facets of UAM ground infrastructure and underscores the need for further research and harmonization to support the development of this transformative mode of urban transportation.

COMBINED REVIEW ON AUTONOMOUS VEHICLE

Understanding Autonomous Vehicles, A Systematic Literature Review on Capability, Impact, Planning And Policy (Asif et al., 2019)

The paper authored by (Asif et al., 2019) delves into the topic of autonomous vehicles and their significant role in advancing smart urban mobilization. The paper's primary objectives are to assess the current state of autonomous vehicles, anticipate future developments in the field, analyze the potential impacts of widespread adoption, and propose actions necessary to achieve desired outcomes for smart urban mobility. The methodology employed for this research includes conducting a systematic review of the existing body of evidence. This review aims to gain a comprehensive understanding of the capabilities, impacts, planning considerations, and policy issues associated with autonomous vehicles. Through this review, the paper identifies the trajectories of technological development in the autonomous vehicle sector, examines the disruptive effects caused by these advancements, explores strategies to address these disruptions, and identifies any potential gaps in the existing literature. To provide a structured approach to the topic, the paper introduces a framework that illustrates key aspects of autonomous vehicle adoption. These aspects include:

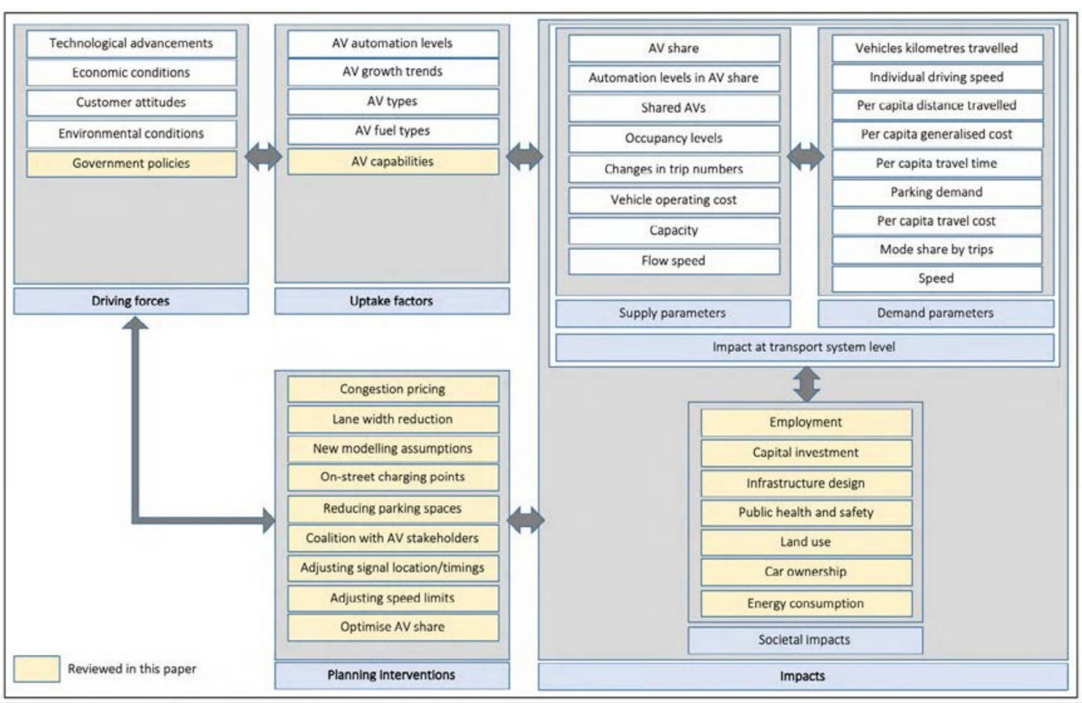

Fig 9. The Framework

1. Driving Force: This component explores the motivations and reasons behind the employment of autonomous vehicles, highlighting the driving factors propelling their adoption.
2. Uptake Factors: Focusing on the capabilities of autonomous vehicles, this aspect examines the factors that influence their uptake, including their technological capabilities and advantages.
3. Planning Intervention: This component addresses the deployment process and strategies for integrating autonomous vehicles into existing urban transportation systems.
4. Impact: Based on an analysis of the advantages and disadvantages of autonomous vehicles to society, this aspect assesses their overall impact on urban mobility.
5. Impact at the Transport Level: This aspect considers the operation of autonomous vehicles within the context of supply and demand parameters, particularly in the realm of urban transportation.

By structuring the discussion around these key components, the paper provides a comprehensive examination of autonomous vehicles' role in shaping smart urban mobility. It sheds light on the current status of autonomous vehicle technology, the potential future scenarios, and the steps necessary to realize the envisioned benefits of smart urban mobility.

The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios (Fagnant & Kockelman, 2014)

Additionally, (Fagnant & Kockelman, 2014) published transportation research on the travel and environmental implications of shared autonomous vehicles (SAVs) using agent-based model scenarios. The paper explores how autonomous vehicles, particularly shared autonomous vehicles (SAVs), have the potential to address challenges commonly encountered by carsharing programs. It introduces an agent-based model and presents case studies to evaluate the environmental impacts and benefits of SAVs in comparison to traditional vehicle ownership and usage. Preliminary findings indicate that SAVs may lead to a reduction in the overall number of vehicles on the road, potentially resulting in positive effects on emissions, even when accounting for increased travel distances. The paper also introduces a well-structured formula designed to address demand and supply issues associated with autonomous vehicles. This formula can be adapted for the operation of Unmanned Aerial Vehicles (UAVs) and offers a comprehensive approach to solving transportation-related challenges.

Block Balance = $SAV_{total}\left(\frac{SAVs_{block}}{SAVs_{total}} + \frac{Demand_{\ block}}{Demand_{\ total}}\right)$ ....(R1)

Where;

SAV = shared autonomous vehicle.

This formula involves 5-minute intervals for different operations.

The following passage outlines a series of vehicle-relocation strategies applied in the context of shared autonomous vehicles (SAVs) operating within an urban area. These strategies aim to effectively distribute SAVs throughout the urban landscape, aligning with anticipated demand, optimizing block-level balances, and enhancing the overall performance of the SAV fleet across various scenarios. Below is a summary of the process:

1. Block Division: The city is divided into 25 large blocks (R1).
2. Block Balance Calculation: For each block, a "block balance" value is calculated based on the expected demand for and supply of SAVs in the upcoming 5-minute period. This balance considers waiting travelers, expected new trips, and the number of free SAVs in the block.
3. Vehicle Relocation: The vehicle-relocation strategy starts by selecting the block with the highest absolute block balance value, either positive or negative (farthest from 0). If the balance is positive, the strategy pushes unused SAVs into adjacent blocks. If negative, it pulls unused SAVs from adjacent blocks.
4. SAV Movement Direction: The number of available SAVs and the block balances of adjacent blocks are determined. SAVs are then selected to be moved based on specific criteria, with the goal of improving the overall block balances.
5. Randomized Starting Point: A corner of the block is chosen randomly to begin the SAV relocation process. SAVs are moved in a clockwise direction from this starting point, following the designated directions for each SAV to be relocated.
6. Zone-to-Zone Movement: SAVs are first moved just over the boundary into the new block. If the initial entry zone is unoccupied, the SAV stops. If not, it continues moving in the

same direction if an unoccupied zone is reachable within a 5-minute travel distance. If not, it seeks the nearest same-direction reachable zone with minimal SAV occupancy until a destination is found.

7. Iterative Process: The process repeats for each block with the largest absolute block balance value until all blocks have either been served (by pushing or pulling SAVs) or the discrepancies are less than 10% of excess demand or supply.

UAV-Enabled Intelligent Transportation Systems (ITS) for the Smart City: Applications and Challenges (Menouar et al., 2017)

This paper discusses the integral role of Intelligent Transportation Systems (ITS) in smart cities and how the integration of connected and autonomous vehicles is essential for next-generation ITS. While these emerging technologies are critical for fully automated transportation systems, the paper emphasizes the need to automate other road and transportation components. Unmanned Aerial Vehicles (UAVs) are proposed as a solution due to their mobility, autonomous capabilities, and communication/processing abilities. The paper explores various ITS applications that can benefit from UAVs and outlines both the potential benefits and challenges associated with using UAVs to enhance ITS in next-generation smart cities. It discusses various applications of UAVs in smart cities, including using UAVs as flying police eyes, flying roadside units, and flying accident report agents. The paper also explores their use in location deployment and path planning.

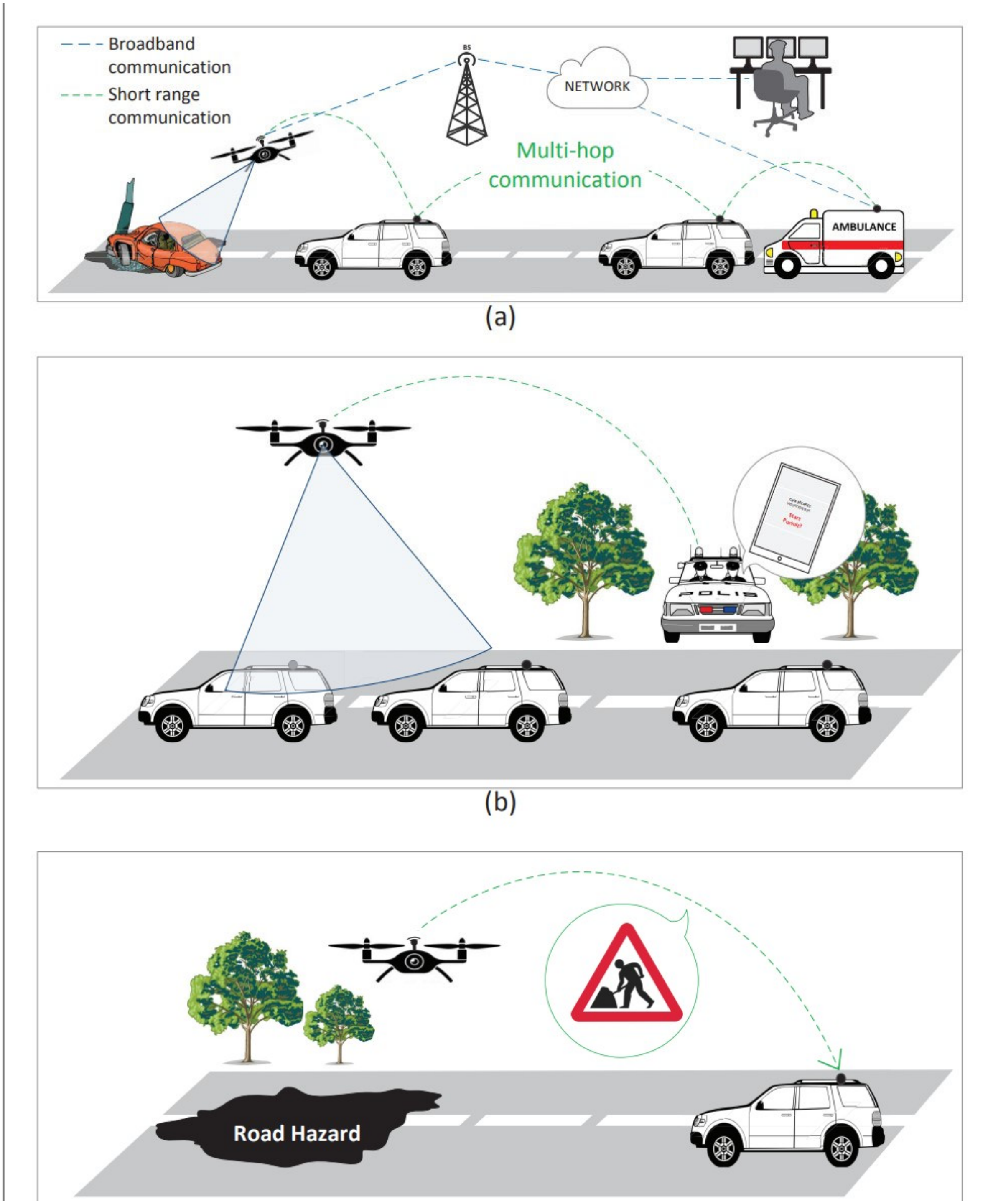

Fig 10. Working principles of UAVs in smart city. (Menouar et al., 2017)

After conducting extensive reviews of current developments in the field of UAM, it became evident that reliable technology is a crucial factor contributing to its advancement. The information gathered from these reviews highlights the significance of tiltrotor technology in providing a long-term solution for cargo transportation within the realm of UAM.

The upcoming sections will delve into the challenges anticipated by tiltrotor technology, how researchers and experts have addressed these challenges, and the areas in need of improvement. This exploration is based on the insights gained from a thorough review of the existing literature on the subject.

CHALLENGES EXPECTED IN TILTROTOR TECHNOLOGY FOR CARGO TRANSPORTATION WITHIN THE CONTEXT OF URBAN AIR MOBILITY.

1. Safety and Certification: Certification procedures, as presented by (Straubinger et al., 2020), play a crucial role in addressing safety challenges related to cargo UAVs in Urban Air Mobility (UAM). These UAVs must align with UAM concepts to ensure safety and regulatory compliance. They should adhere to evolving aviation standards, including passenger capacity limits, maximum take-off mass, and fail-safe capabilities. Collaboration with airspace management agencies, such as U-space, is essential to establish safe airspace access. Rigorous training for cargo UAV pilots and operators is necessary to prevent misuse and enhance safety. Regular database updates are vital to avoid obstacles. Following these procedures will ensure successful integration into urban airspace, providing robust solutions for safety and compliance.

2. Infrastructure: Unlike passenger-focused UAM, Tiltrotor UAVs for cargo transportation require smaller vertiports, often located atop buildings or at company bases. These compact vertiports offer convenience and efficient cargo handling. Vertiports can adopt operational mechanisms similar to those proposed by (Bharadwaj et al., 2021), where regional movements are managed by vertiport operators, facilitating seamless cargo transfer between bases.

3. Noise Pollution: Tiltrotor UAVs have the potential to generate noise, which varies based on design and operational factors. However, they offer reduced noise compared to traditional VTOL UAVs, especially during horizontal flight. (Straubinger et al., 2020) literature review provides insights into mitigating noise pollution. Selecting suitable vertiport locations away from noise-sensitive areas, such as airports or train stations, is crucial.

4. Payload and Range: Cargo UAVs must possess sufficient payload capacity and range to be economically viable. Balancing payload capacity and infrastructure size while minimizing noise in urban areas is challenging. Regulations should set design limits for tiltrotor UAVs based on their intended cargo capacity to guide manufacturers and operators.

5. Weather: Adverse weather conditions can disrupt UAV operations. Robust weather resilience and contingency plans are essential. Collaboration between cargo UAV companies and Airspace Management Agencies for weather condition reports is necessary to ensure safe and efficient cargo transportation.

6. Public Acceptance: Convincing the public about the safety and benefits of cargo UAVs in urban areas is crucial. Surveys, as addressed in existing literature, suggest that as technology improves, public adoption of UAVs is likely. Tiltrotor cargo UAVs, if proven efficient and reliable, have the potential to gain public acceptance. Careful planning of integration, certification, and operational processes is vital, similar to how certain car brands gain priority in specific countries based on meeting local demands. Cargo UAVs could follow a similar adoption pattern.

Tiltrotor UAVs offer solutions to various logistical challenges associated with cargo transportation, including accessibility, infrastructure, speed, cost-effectiveness, versatility, and environmental considerations. Their unique capability to combine vertical takeoff and landing with efficient forward flight positions them as a promising technology to address these challenges across various industries and applications.

ADVANTAGES OF TILTROTOR UAVS FOR CARGO TRANSPORTATION

1. Range: Tiltrotor UAVs boast impressive range capabilities, outperforming purely rotary-wing drones. The hybrid takeoff and landing (HTOL) feature significantly enhances flight speed compared to traditional rotary-wing drones. This extended range equips them for efficient cargo transportation between distant locations. Tiltrotor UAVs excel in fulfilling on-demand cargo services and can access remote areas with ease. Examples include serving offshore platforms, reaching disaster-stricken regions, and aiding rural communities. Moreover, they are invaluable in responding to urgent needs, particularly in emergency situations like natural disasters or medical emergencies. These UAVs swiftly transport essential supplies, such as medical equipment, food, and relief materials, to affected areas. Their speed plays a crucial role in mitigating traffic congestion, as they bypass terrestrial traffic, delivering cargo directly to destinations. This reduces delivery times and alleviates congestion-related problems.

2. Reduced Infrastructure Dependency: Tiltrotor UAVs differ from traditional cargo aircraft by not relying on extensive runway infrastructure for takeoff and landing. Their vertical takeoff and landing capability eliminate the need for long runways, which is particularly advantageous in regions with limited infrastructure. This feature makes them well-suited for urban usage and integration. Challenges related to airspace management during flight have been addressed earlier in this paper, drawing from insights gained through literature review.

3. Safety and Environmental Benefits: Electric or hybrid tiltrotor UAVs offer significant environmental benefits by reducing greenhouse gas emissions when compared to conventional cargo planes. They are also known for generating less noise pollution, making them suitable for urban cargo operations. Noise production by UAVs is primarily influenced by their size, which means that densely populated urban areas can employ smaller UAVs for operations. Tiltrotor UAVs also present a cost-effective solution for

cargo transportation, particularly for time-sensitive or specialized cargo. They achieve operational savings by reducing the reliance on ground transportation, which is prone to fuel and labor costs.

In terms of safety, tiltrotor UAVs for cargo play a crucial role in mitigating risks to human pilots and ground crews, especially in challenging or hazardous environments. Cargo can be delivered without exposing human operators to dangerous conditions. The primary appeal of tiltrotor UAVs lies in their efficiency, driven by their unique mode of operation. The following section examines real-world scenarios where tiltrotor UAVs can be effectively deployed.

CASE STUDIES IN THE USE OF TILT-ROTOR UAVS FOR CARGO TRANSPORTATION

Case Study 1: Urban Medical Supplies Delivery

- In a congested urban area with frequent traffic jams, the need for rapid medical supplies delivery is critical. Tiltrotor UAVs present an innovative solution to this challenge. We examine a case where a hospital network collaborates with a UAV logistics provider to deliver medical supplies to various healthcare facilities across the city.

- Implementation Strategy: The implementation involves establishing a dedicated UAV logistics hub on the hospital premises. Medical supplies are loaded onto tiltrotor UAVs, which take off vertically and transition to horizontal flight for faster transit. The UAVs follow predetermined routes, avoiding congested areas, and can make precise deliveries to hospitals, clinics, and emergency response units.

- Benefits: This case study demonstrates the potential benefits of tiltrotor UAVs in urban cargo transportation. Medical supplies, including life-saving medications and equipment, can be delivered within minutes, improving patient care and saving lives. Reduced transportation times, minimized road congestion, and lower delivery costs are among the key advantages.

Case Study 2: High-Value Document and Parcel Transport for Financial Institutions

- In urban centers with numerous financial institutions, securely transporting high-value documents and parcels between bank branches, offices, and central processing centers is essential. Tiltrotor UAVs can offer a secure and efficient solution.

- Implementation Strategy: Banks and financial institutions collaborate with UAV logistics providers to establish secure transit routes for tiltrotor UAVs. These routes are monitored and protected to prevent unauthorized access. Tiltrotor UAVs are used to transport sensitive documents, such as financial statements, contracts, or cash, between locations.

- Benefits: The utilization of tiltrotor UAVs ensures the safe and timely delivery of critical financial documents. Reduced transit times minimize security risks and operational costs for financial institutions, making this an attractive solution in dense urban settings. This can also safe life, robbery and theft.

Case Study 3: Fresh Produce Delivery to Urban Farmers' Markets

- Urban agriculture and farmers' markets are on the rise in many cities. Delivering fresh produce from local farms to urban markets can be a logistical challenge. Tiltrotor UAVs can facilitate the rapid movement of farm-fresh goods.

- Implementation Strategy: Local farmers and cooperative agricultural organizations partner with UAV operators to create a sustainable supply chain. Tiltrotor UAVs with specialized cargo compartments transport freshly harvested fruits, vegetables, and other agricultural products from rural farms to urban farmers' markets. This approach reduces the time between harvesting and selling, ensuring the freshness of the produce.

- Benefits: Tiltrotor UAVs support local agriculture and the availability of fresh, locally grown produce in urban areas. They reduce the carbon footprint associated with long-haul transportation, promoting sustainability and healthier urban living.

CONCLUSION

This research has delved into the promising realm of Urban Air Mobility (UAM) and its potential to revolutionize cargo logistics in urban environments. We have explored the significant challenges that UAM faces, particularly the constraints posed by limited infrastructure and the demand for adaptable aerial vehicles capable of navigating confined spaces while maintaining cargo capacity. Throughout this study, tiltrotor Unmanned Aerial Vehicles (UAVs) have emerged as a pivotal solution to these challenges. Their unique combination of vertical takeoff and landing (VTOL) with efficient forward flight positions them as ideal candidates for urban cargo transportation. We have thoroughly evaluated tiltrotor UAVs, focusing on their operational efficiency, safety, and economic viability. The findings of this research underscore the transformative potential of tiltrotor technology, signaling a significant advancement in the realm of UAM for cargo transportation within urban areas. Our study not only contributes valuable insights to the ongoing discourse on UAM integration but also lays a solid foundation for future developments in autonomous aerial cargo delivery systems.

As we move forward, the integration of tiltrotor UAVs stands as a promising solution, offering the prospect of more efficient, safer, and environmentally sustainable cargo transportation in our ever-evolving urban landscapes. This research represents a crucial step in harnessing the full potential of tiltrotor technology to address the complex challenges of urban cargo logistics and pave the way for a more connected and efficient future.

REFERENCE

Al Haddad, C., Chaniotakis, E., Straubinger, A., Plötner, K., & Antoniou, C. (2020). Factors affecting the adoption and use of urban air mobility. *Transportation Research Part A: Policy and Practice*, *132*(March 2019), 696–712. https://doi.org/10.1016/j.tra.2019.12.020

Asif, F., Md, K., Tan, Y., & Graham, C. (2019). Understanding autonomous vehicles A systematic literature review on capability, impact, planning and policy. *Journal of Transport and Land Use*, *12*(1), 45–72. https://www.jstor.org/stable/26911258

Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, *67*, 1–14. https://doi.org/10.1016/j.trc.2016.01.019

Bauranov, A., & Rakas, J. (2021). Designing airspace for urban air mobility: A review of concepts and approaches. *Progress in Aerospace Sciences*, *125*. https://doi.org/10.1016/j.paerosci.2021.100726

Bharadwaj, S., Carr, S. P., Neogi, N. A., & Topcu, U. (2021). Decentralized Control Synthesis for Air Traffic Management in Urban Air Mobility. *IEEE Transactions on Control of Network Systems*, *XX*(XX), 1–11. https://doi.org/10.1109/TCNS.2021.3059847

Bulusu, V., Onat, E. B., Sengupta, R., Yedavalli, P., & MacFarlane, J. (2021). A Traffic Demand Analysis Method for Urban Air Mobility. *IEEE Transactions on Intelligent Transportation Systems*, *22*(9), 6039–6047. https://doi.org/10.1109/TITS.2021.3052229

Çetin, E., Cano, A., Deransy, R., Tres, S., & Barrado, C. (2022). Implementing Mitigations for Improving Societal Acceptance of Urban Air Mobility. *Drones*, *6*(2), 1–19. https://doi.org/10.3390/drones6020028

Cohen, A., & Shaheen, S. (2021). Urban Air Mobility: Opportunities and Obstacles. *International Encyclopedia of Transportation: Volume 1-7*, *5*, 702–709. https://doi.org/10.1016/B978-0-08-102671-7.10764-X

CZECH, P. (2018). Autonomous vehicles: basic issues. *Scientific Journal of Silesian University of Technology. Series Transport*, *100*, 15–22. https://doi.org/10.20858/sjsutst.2018.100.2