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Editorial

Flying cars and urban air mobility: Redefining cities in three dimensions

1. Limitation of ground transportation

The rapid pace of urbanization, while driving population concentration and economic prosperity, has simultaneously exacerbated the structural imbalance between transportation supply and demand. The multifunctional nature of urban land limits the expansion of transport infrastructure, whereas the inherent rigidity of existing networks hinders swift adaptation. Such physical rigidity is reflected not only in prolonged construction cycles and high renovation costs, but also in the mismatch between planning structures and the dynamic growth of urban needs (Lu et al., 2021). During peak commuting hours, the surge in private vehicle usage often overwhelms limited road capacity (as illustrated by the Shenzhen case in Fig. 1), whereas during off-peak periods, a large proportion of infrastructure remains underutilized. This pronounced spatiotemporal asymmetry in resource allocation exposes a fundamental shortcoming of two-dimensional transportation modes under land constraints: they can neither alleviate peak-hour pressure through spatial expansion nor achieve optimal utilization of existing capacity.

Conventional urban congestion mitigation strategies primarily follow two paths. The first is an infrastructure-centric approach that focuses on boosting the capacity of individual transport carriers, such as metro systems. However, this approach often entails high capital investment, long construction timelines, and limited flexibility in adapting to rapidly changing travel patterns. The second path leverages intelligent transportation systems, employing measures such as reversible lanes and demand-responsive transit to enhance system resilience (Rani and Sharma, 2023). While both approaches can alleviate demand–supply imbalances, neither can overcome the rigid land constraints of dense urban environments. Moreover, physical capacity expansion is susceptible to induced demand, causing congestion to resurface over time, particularly in cities with pronounced jobs–housing imbalances and mono-centric development patterns.

Expanding the transportation system from two to three dimensions through urban air mobility (UAM) offers a promising pathway to address the aforementioned constraints (Fig. 2). This paper examines the rise of UAM and flying cars, evaluating their transformative potential for existing transportation systems and analyzing their development characteristics alongside the key challenges that must be addressed.

2. Appearance of flying cars

By operating in urban airspace, flying cars can bypass ground traffic congestion and natural barriers, offering a rapid and flexible travel option for passengers with urgent mobility needs. Flying cars also provide a more private and personalized experience compared to conventional public transportation (Wang and Qu, 2023). Although helicopters can deliver similar services, their high operating costs and substantial noise emissions make them unsuitable for frequent urban commuting. In contrast, electric-powered flying cars are designed to be quieter, more energy-efficient, and more cost-effective, creating favorable conditions for the widespread adoption of UAM.

The concept of flying cars dates back to 1917 with the introduction of the “Autoplane”, an early design featuring detachable wings. However, technological limitations at the time prevented its development into a practical transportation mode. In recent years, the convergence of electrification and intelligent systems has revitalized the concept, demonstrating both its feasibility and potential. For instance, NASA's 2009 Puffin concept validated the viability of electric propulsion for vertical flight (Moore, 2010). Subsequent initiatives have reinforced the industry's commitment to this emerging field: Airbus launched the Vahana project in 2016 to advance self-piloted, electric VTOL aircraft, while Boeing's full acquisition of Wisk Aero signaled a strong investment in next-generation eVTOL technology. In parallel, spurred by government policies aimed at fostering a low-altitude economy, China has made significant progress, with companies such as EHang, AutoFlight, XPeng, and Aerofugia emerging as industry leaders.

As flying car technologies continue to evolve, multiple distinct configurations have been developed, such as:

- **Multirotor eVTOLs.** Represented by designs such as the EHang 216 (Fig. 3a), these vehicles have no fixed wings and rely solely on multiple rotors for both lift and thrust. Typically seating 2–3 passengers, they are optimized for short-range (10–30 km), high-maneuverability operations in dense urban environments.
- **Winged eVTOLs.** Exemplified by the wisk generation 6 (Fig. 3b), these aircraft use rotors for vertical takeoff and landing and incorporate fixed wings to generate lift during cruise, thereby improving efficiency and range. This category includes tiltrotor and lift-plus-cruise configurations. They offer higher speeds, longer ranges (30–150 km), and greater payload capacities, with seating for 3–7 passengers to allow more cost-effective long-distance operations.
- **Modular flying cars.** Such as the Tsinghua modular flying car (Fig. 3c), these vehicles address the “three-stage transfer” challenge in conventional eVTOL operations, where passengers must travel from their origin to a vertiport, fly to another vertiport, and then continue by ground transport to their final destination. By integrating the flight capabilities of eVTOLs with the flexibility of ground vehicles, modular flying cars enable seamless door-to-door travel, broadening the practical applications of UAM services.

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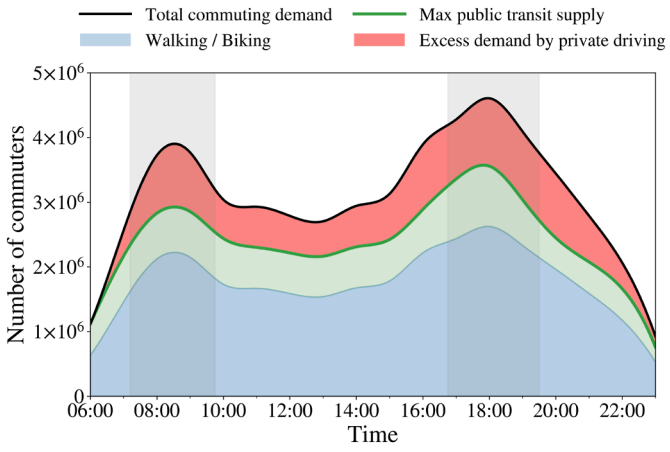


Fig. 1. Imbalance between commuting demand and transportation supply in Shenzhen, China.

3. Technical and operational requirements for flying car deployment

Flying cars integrate a range of advanced technologies that enable safe, efficient, and scalable operations in urban air mobility systems. Their successful deployment depends on several key enablers: electrification, autonomous systems, industrial integration, and advanced low-altitude traffic management.

3.1. Electrification and distributed propulsion

Electrification endows flying cars with precise control and distributed propulsion, allocating power across multiple units to ensure redundancy and sustained flight even in the event of individual unit failures. The high responsiveness and accuracy of electric motors not only enhance maneuverability and improve safety in emergency handling but also provide the agility needed to support advanced tactical deconfliction methods, such as AI-powered speed adjustments in congested airspace. Compared with conventional internal combustion engine systems, electric propulsion involves 30%–50% fewer components, resulting in reduced weight, lower failure rates, and simplified maintenance, thereby improving robustness and lowering operating costs. Moreover, electric systems generate less noise and zero direct emissions, making eVTOL aircraft more environmentally sustainable and socially acceptable than traditional helicopters. Collectively, these attributes contribute to safer, cheaper, and more practical air taxi operations, supporting the vision of urban air mobility as a viable mode for daily commuting.

3.2. Autonomy and safety assurance systems

Autonomous technologies form the backbone of intelligent flight systems for flying cars, enabling safe operation in complex low-altitude urban airspace. Flying cars must have the ability of self-decision making to respond to sudden safety threats, including dynamic threats such as birds or unmanned aerial vehicles; static obstacles like terrain, buildings, and cranes; and sudden weather events such as gusts, turbulence, or precipitation. They must also be prepared for operational

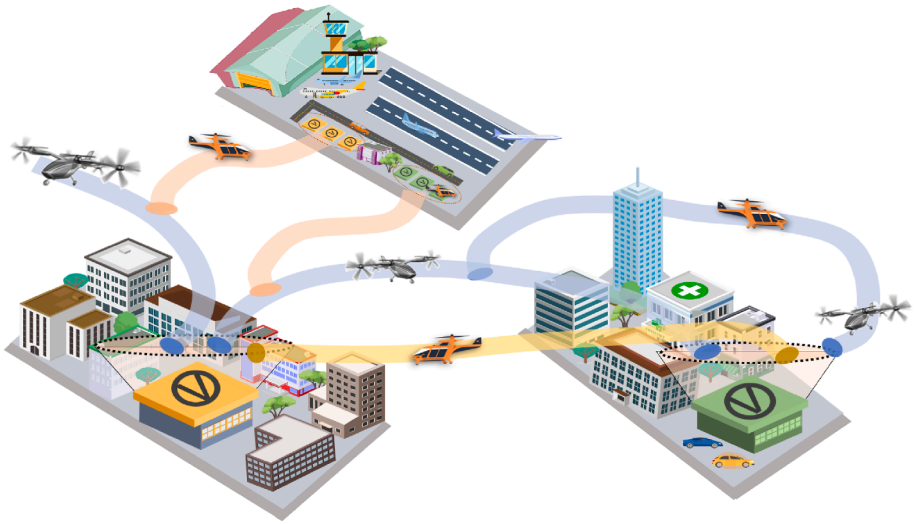


Fig. 2. Envisioned urban air mobility ecosystem.



(a) EHang 216 aircraft **(b)** Wisk generation 6 aircraft **(c)** Tsinghua modular flying car

Fig. 3. Different platforms of flying cars.

emergencies, including communication, navigation, or positioning failures, as well as power system malfunctions.

Given these challenges and the potentially severe consequences of accidents, high levels of autonomy are essential. During various phases of flight, such as takeoff, cruising, and landing, flying cars rely on centralized command systems, inter-aircraft communication, and multi-source data integration to maintain situational awareness. By applying risk assessment models, they can predict potential conflicts and autonomously execute obstacle avoidance maneuvers or navigation adjustments, ensuring operational safety and reliability.

3.3. Industrial integration and supply chain synergy

From an industrial perspective, the automotive supply chain will be pivotal, as the success of flying cars depends on achieving mass production at affordable costs rather than relying on the low-volume, high-cost model of traditional aerospace manufacturing. The automotive sector already possesses mature capabilities in large-scale production, modular design, and stringent quality control, all of which are essential to ensure that flying cars can be produced consistently, safely, and at a price point suitable for daily commuting (Berckman et al., 2023). Key components like batteries, motors, power electronics/controllers, communication and navigation systems, and lightweight structural materials can be integrated within a unified, high-throughput production flow. By leveraging established automotive practices and infrastructure, flying cars are expected to transition from bespoke prototypes to standardized products built on automated assembly lines, enabling both cost reduction and reliable performance at scale.

However, despite these synergies, certain technical requirements for flying cars are far more stringent than those of road vehicles, with energy storage representing the most critical challenge (Yang et al., 2021). Current vehicle-grade lithium-ion cells typically provide < 250 Wh/kg, with advanced ternary chemistries at 250–300 Wh/kg, whereas commercial flying cars will likely require ≥ 400 Wh/kg and batteries capable of sustaining charge and discharge at rates exceeding five times their nominal capacity (i.e., $\geq 5C$), not only to deliver the power required for vertical takeoff and landing but also to enable rapid charging and minimize idling time at vertiports, which is essential for large-scale commercial operations. Accordingly, industry R&D is pursuing higher-specific-energy chemistries (e.g., lithium–sulfur, lithium–air), high-power battery packs with robust battery-management systems, and enhanced thermal solutions (e.g., two-phase or immersion cooling and advanced heat-spreader materials).

3.4. Low-altitude traffic management and regulatory framework

The widespread adoption of flying cars depends not only on advances in vehicle technologies but also on the establishment of a robust traffic control and regulatory framework (Federal Aviation Administration, 2023). Unlike conventional commercial aviation, the urban low-altitude environment is inherently complex, characterized by high density, high dynamics, and pronounced heterogeneity. Numerous flights must compete for limited airspace and takeoff/landing resources, while urban obstructions, meteorological disturbances, and the complex electromagnetic environment near the ground intensify operational dynamics, and different vehicle configurations and operation entities amplify the heterogeneity of the airspace.

Looking ahead, future low-altitude traffic management must evolve beyond the traditional static "approval-based" model toward a proactive and adaptive service paradigm. One approach is the free-fly concept, which allows aircraft to follow flexible four-dimensional trajectories rather than fixed routes. It relies on optimization algorithms, supported by techniques such as geofencing and time–space cell allocation, to dynamically compute and deconflict trajectories in real time (Stevens and Atkins, 2020). Another approach is the structured airspace model, which, similar to ground transportation, organizes flights within pre-defined corridors, simplifying management but limiting flexibility. Ensuring safety and efficiency requires integrating strategic and tactical conflict management, using measures such as ground delays and real-time deconfliction to maintain safe separation (Chen et al., 2024). The hybrid architecture, which combines free-fly flexibility with structured policies, represents a promising direction. This not only enhances efficiency but also strengthens resilience against unexpected risks, fostering a safe, efficient, and inclusive environment for large-scale flying car operations.

4. Conclusions

The exploration of flying cars underscores both their transformative potential and the challenges that must be overcome for large-scale adoption. Expanding urban mobility into three dimensions offers a compelling response to the growing imbalance between demand and supply on the ground, but success depends on advances in vehicle technologies, industrial practices, and regulatory systems. Electrification, distributed propulsion, and autonomy provide the technical foundation for safe and efficient operations, while the shift toward mass production promises to reduce costs and enhance reliability. At the same time, aviation's stringent requirements, particularly in energy systems and certification, demand higher standards than those of the automotive industry. Ultimately, the creation of a dedicated low-altitude traffic management and regulatory framework will be decisive in shaping a safe, resilient, and scalable ecosystem, ensuring that flying cars evolve from a promising concept into an integral component of future urban transportation.

CRediT authorship contribution statement

Di Lv: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Kai Wang:** Writing – review & editing, Writing – original draft, Supervision, Resources, Conceptualization. **Shulu Chen:** Resources, Visualization, Writing – review & editing. **Xiaobo Qu:** Writing – review & editing, Writing – original draft, Validation, Resources, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The author Xiaobo Qu is the Editor-in-Chief of this journal.

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