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Urban Air Mobility: Opportunities and Obstacles

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Abbreviations

eVTOL	electric vertical take-off and land
UAM	urban air mobility
UAS	unmanned aerial systems
UTM	unmanned aircraft systems traffic management
AAM	advanced air mobility
VTOL	vertical take-off and land

Introduction: What is Urban Air Mobility and On-Demand Aviation?

Urban Air Mobility (UAM) (also known as advanced air mobility) is an emerging concept that envisions a safe, sustainable, affordable, and accessible air transportation system for emergency management, cargo delivery, and passenger mobility within or traversing a metropolitan area. UAM is part of a broader ecosystem of on-demand mobility where consumers can access mobility and goods delivery services on demand by dispatching or using urban aviation services, courier services, shared automated vehicles, shared mobility, public transportation, and other innovative and emerging transportation technologies.

Across the globe, a number of converging innovations, such as advancements (e.g., vertical lift, electrification, and automation) and the growth of app-based services are contributing to the concept of on-demand aviation, including UAM and rural air mobility (for less urbanized areas). Although the concept of UAM is not new - several helicopter services began providing early UAM services in Los Angeles, New York City, San Francisco, and other metropolitan areas in the 1950s, 1960s, and 1970s. In recent years, on- demand aviation services similar to transportation network companies (TNCs) dispatched through a smartphone app have entered the marketplace (Cohen et al., 2020). For example, in the United States, BLADE provides helicopter services booked through a smartphone app in numerous cities (e.g., Los Angeles, Miami, New York City, and San Francisco). BLADE employs third-party operators that own, manage, and maintain their aircraft under federal regulations that govern intrastate air taxis and commuter services (BLADE, 2019). Similar helicopter services, such as Airbus' Voom are operational in Mexico City, Sao Paulo, and the San Francisco Bay Area. Travelers can use Voom to request on-demand flights from partner air taxi companies. Trips can be booked anytime between one hour to 90 days in advance through the Voom app or website (Voom, 2020).

In recent years, several companies are developing and testing enabling elements of a contemporary UAM concept including prototypes of vertical take-off and landing (VTOL) capable aircraft, operational concepts, and market studies to understand potential business models. Original equipment manufacturers are developing a variety of piloted, remote piloted, partially automated, and fully autonomous aircraft for a variety of applications. Common terms and definitions are summarized in Table 1.

In the United States, The National Aeronautics and Space Administration's (NASA) Advanced Air Mobility (AAM) National Campaign aims to improve UAM safety and accelerate scalability through demonstrations beginning in 2020. In addition to public sector research, a number of TNCs, such as Uber and Grab, are also working to develop their own UAM delivery and passenger services in partnership with electric VTOL (eVTOL) aircraft and small unmanned aerial systems (also known as sUAS and drone) manufacturers. A number of planned delivery services (for consumer goods and medical supplies) using sUAS/drones are being explored. Planned passenger services using eVTOL include Dallas, Los Angeles, Melbourne, and Singapore (Etherington, 2020; Hawkins, 2017).

Table 1. Common Terms and Definitions

Term	Definition
Rural Air Mobility	Envisions a safe, sustainable, affordable, and accessible air transportation system for passenger mobility, goods
Small Unmanned Aircraft	Aircraft that weigh less than 55 pounds (or 25 kg) on take-off, including everything that is on board or attached
Small Unmanned Aircraft Systems (sUAS)	Small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system.
Urban Air Mobility (UAM)	Envisions a safe, sustainable, affordable, and accessible air transportation system for passenger mobility, goods
Unmanned Aircraft Systems Traffic Management (UTM)	A traffic management system that provides airspace integration requirements, enabling safe low-altitude operations. UTM provides services such as: airspace design, corridors, dynamic geofencing, weather avoidance, and route planning.
Vertical Take-Off and Land (VTOL)	An aircraft that can take off, hover, and land vertically.

While UAM may be enabled by the convergence of several factors, several challenges such as: community acceptance, safety, social equity, issues around planning and implementation, airspace, and operations, could create barriers to mainstreaming. While numerous societal concerns have been raised about these approaches (e.g., privacy, safety, security, social equity), on-demand aviation has the potential to offer additional options for emergency services, goods delivery, and passenger mobility in urban and rural areas using small piloted, remote piloted, and autonomous aircraft (Shaheen et al., 2020).

This chapter is organized into four sections. The first section discusses potential barriers and challenges to implementation. Next, potential use cases of UAM are discussed. In the third section, the role of research, regulation, and demonstrations in developing policies and programs to guide the use of on-demand aviation are discussed. The chapter concludes with a discussion of how COVID-19 is presenting opportunities to demonstrate medical, emergency response, and sanitation use cases to build community acceptance of this novel aviation concept.

Potential Barriers and Challenges

Renewed interest in on-demand aviation coupled with innovative and emerging technologies has increased awareness about potential UAM societal concerns. In spite of an array of potential use cases and applications for on-demand aviation, UAM could face notable safety, financial, and community acceptance challenges, among others. Potential challenges to UAM deployment and adoption are summarized in Table 2.

Potential UAM Use Cases

UAM may serve a variety of use cases, such as emergency response, goods delivery, and passenger mobility and has the potential to:

- Support emergency management missions including: air ambulance, emergency supply delivery, organ transport, and search and rescue operations;
- Expand access to goods delivery, particularly in remote locations; and
- Enable additional mobility and delivery options.

A few potential UAM market segments and service models are described in Table 3.

There is a lack of research and understanding about the: (1) environmental, (2) travel behavior, (3) lifecycle, and (4) surface transportation network effects of implementing UAM. Research, pilot projects, and public policies could help to address many UAM concerns.

The Role of Research Pilot Demonstrations, and Regulation

Due to the exploratory nature of UAM, more research is needed to better understand the potential impacts of UAM. Numerous efforts are underway across the globe to explore potential UAM opportunities and challenges to guide the use of on-demand aviation.

A few research gaps include:

- How will travelers' access vertiports, both from their origin and to their destination?
- How will UAM impact modal shift? Will UAM remove enough vehicles from the surface transportation network to make a noticeable impact on congestion? Could UAM induce travel demand due to reduced travel times or encourage more people to drive (due to reduced congestion from travelers switching to UAM)?
- How many gas-powered vehicles could UAM remove from the road?
- What are the lifecycle emission impacts associated with UAM compared to other transportation modes?
- What are the broad land use and societal impacts of UAM on communities?

Table 2. Potential barriers and challenges to UAM deployment and adoption

Potential Opportunities and Challenges	Description	Use Case		
		Emergency Response and Management	**Goods**	**Delivery**
Passenger Mobility and Affordability and Social Equity	With respect to passenger mobility, current UAM passenger services are premium offerings that have, in recent years, typically averaged $149–300 US per seat using traditional helicopters. At present, there are concerns that UAM may not be an affordable transportation option by lower- and middle-income households, and UAM may be used by upper income households to avoid congestion. Electrification and automation of UAM could reduce costs; however, uncertainty exists about whether UAM can obtain mass-market affordability. Additionally, it is important for UAM to be accessible for people with disabilities and other users with special needs. Similar concerns about affordability could also be associated with some emergency response use cases, such as medical transport (e.g., people without any or sufficient levels of medical insurance coverage may not be able to afford aeromedical use cases and/or be left with unaffordable medical transportation bills after using the service).	X		X
Aesthetics and Visual Pollution	An overcrowding of low-altitude aircraft in urbanized areas could create unwanted visual disturbances, particularly for non-essential use as mobility that could be accomplished with surface modes and drone delivery for retail packages.		X	X
Noise Pollution	Noise pollution is a potential problem that could arise with multiple low-altitude aircraft in urban areas. In the future, the use of conventional helicopters for early UAM passenger mobility service could increase community concerns about noise and limit adoption, particularly for non-essential use cases, such as passenger mobility and retail goods delivery. UAM may need to meet a stricter noise standard due to multiple aircraft, rotorcraft, and drones operating a low altitude overpopulated urban areas.		X	X
Increased Aircraft Activity Over Residential Areas	Residential communities may be concerned with low-altitude aircraft flying over homes and yards due to safety, privacy, noise, aesthetic, and other concerns. For example, residential communities could be particularly concerned about during the evenings, late night, and weekends due to concerns about privacy and noise disturbances at times when most residents are sleeping		X	X
Electrification and Range Anxiety	While electrification has the potential to offer reduced emissions, scaled UAM operations could have an impact on the electric grid. Additionally, there could be performance and safety concerns associated with battery weight and energy storage in different climates, as well as consumer concerns associated with range anxiety. For emergency response use cases employing larger aircraft (e.g., air ambulance),	X		X

Potential Opportunities and Challenges	Description	Use Case		
		Emergency Response and Management	Goods	Delivery
	electrification and range limitations could be notable barriers to adoption. Emergency response use cases with electric aircraft create notable operational challenges that must be considered, such as increased downtime due to charging and reduced mission flexibility due to limited range (requiring an aircraft to return to its base for recharging). This can result in greater downtime for electric aircraft compared to hybrid and gas-powered alternatives, including existing air ambulance services using helicopters. Technological innovations, such as improved battery capacity, reduced charging times, and battery swapping could help overcome some of these limitations.			
Remotely Piloted and Autonomous Operations	There are a variety of technical and operational challenges that must be overcome before UAM can be deployed in urban areas at scale. In particular, there could be community concerns associated with remotely piloted and autonomous aircraft (both from the perspective of users and non-users). Machine learning and other algorithms used for automation are non-deterministic, which means that even for the same input, the algorithm may exhibit different behaviors on different runs. This could present challenges for certifying that these systems are safe for autonomous flight. Finally, there are a number of technical and security concerns (i.e., unmanned traffic management and cybersecurity) that will need to be addressed to accommodate remotely piloted and autonomous operations.	X	X	X
Airspace and Unmanned Traffic Management (UTM)	Integrating innovative and emerging aviation technologies into an existing, antiquated, and analog system of air traffic management can pose notable challenges for UAM, particularly as the number of new users of low-altitude airspace is projected to increase. A core challenge is enabling an automated air traffic management system that can handle increasing flight activity into a single ecosystem that accommodates an array of airspace users and communication methods. Designing a system that leverages the latest innovations, while ensuring cybersecurity and backward compatibility with existing systems, could be key.	X	X	X
Safety and Certification	Concerns about safety, particularly with new aircraft types coupled with scaled operations over highly urbanized areas could present challenges for UAM. Additionally, most aviation authorities lack defined certification categories for UAM aircraft that in many cases may contain novel features and combinations of features that are not typically found in other aircraft (distributed electric propulsion/tilt-wing propulsion, VTOL, autonomy hardware and software, and others). For goods delivery use cases, in	X	X	X

Potential Opportunities and Challenges	Description	Use Case		
		Emergency Response and Management	Goods	Delivery
	particular, potential interactions between untrained individuals and drones could present significant safety challenges.			
Business Model and Financial Sustainability	Each category of use cases presents their own business model and financial challenges. For the emergency response use case, a NASA market study examining the viability of air ambulance vehicles found that electric VTOL aircraft, in the best case scenarios, could only yield nominal cost savings over helicopters due to the high fixed costs of flight crews and medical personnel, limited range, and increased operational complexities. Drone delivery presents related challenges. A ratio of one drone to one package is likely an inefficient method of delivering a network of packages to a community. While early launches using eVTOL aircraft are expected in the early to mid-2020s, profitable passenger services are not anticipated until the late-2020s and early-2030s, based on exploratory market studies.	X	X	X

Source: (Shaheen et al. 2018; Reiche et al. 2018; Serrao et al. 2018; McKinsey and Company 2018)

Table 3. Potential UAM market segments and service models

Market Segment	Service Models
Emergency Management and Response	• *Medial Response, Evacuation, and Transport*—Providing medical care, evacuating patients from an incident scene, and transporting them to medical facilities • *Disaster Response*—An array of missions that could include warning/evacuation, search and rescue, firefighting, assessing damage, providing immediate assistance, and restoring critical infrastructure • *Disaster Relief*—An array of missions to help provide relief to return a community back to normal following an incident or disaster (e.g., distributing food and supplies)
Goods Delivery	• *Small Unmanned Aircraft Systems (sUAS)* —A small aircraft (and enabling elements such as communication links) that weighs less than 55 pounds on take-off, including everything that is on board or otherwise attached (i.e., a package)
Passenger Mobility	• *Personal Aircraft*—An aircraft that serves an individual or party for a length of time greater than the duration of a single flight • *Air Pooling* —An on-demand service where multiple individual users share an aircraft • *Air Taxi*—An on-demand service for a single user or group of users that reserve an entire aircraft for a flight and determine theflight's origin, destination, and timing • *Semi-Scheduled Service*—A model with semi-flexible scheduling that can be modified to meet a customer's preferences (e.g., a flight scheduled to depart within a 2-h window) • *Scheduled Service*—Offering near on-demand by offering frequent flights along a route with regularly scheduled service

Source: (Reiche et al. 2018; Patterson et al. 2018; McKinsey and Company 2018)

More research is needed to:

- Study the environmental impacts of UAM implementation and policies to support sustainability;
- Understand how to integrate UAM and small UAS (i.e., drones) into the same airspace and traffic management system;
- Research the safety and health impacts of UAM (including personal safety onboard autonomous aircraft, such as crime);
- Identify data needs, including data metrics, data formats, and standards for sharing;
- Model the potential traffic and land use impacts of UAM on the community;
- Identify flight path profiles for innovative aircraft and if traditional helipad approach paths should be adapted or changed;
- Understand public perception of aviation technologies, such as issues associated with electric range anxiety, willingness to fly on autonomous aircraft, etc.;
- Identify best practices for multimodal integration and vertiport design; and
- Study the social equity and economic impacts of UAM on communities (e.g., opportunities for increased employment, reduced ground vehicle traffic, accessibility for UAM by disadvantaged communities and users with special needs) (Fig. 1).

A number of public sector initiatives have begun to explore these unanswered questions and challenges. Key research, demonstration, and regulatory developments from the National Aeronautics and Space Administration (NASA), the US Federal Aviation Administration (FAA), the European Union Aviation Safety Agency (EASA), and the International Civil Aviation Organization (ICAO) are summarized further.

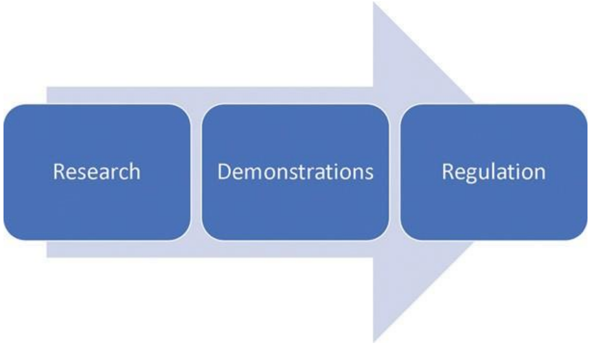

Figure 1 Understanding and guiding the potential UAM impacts.

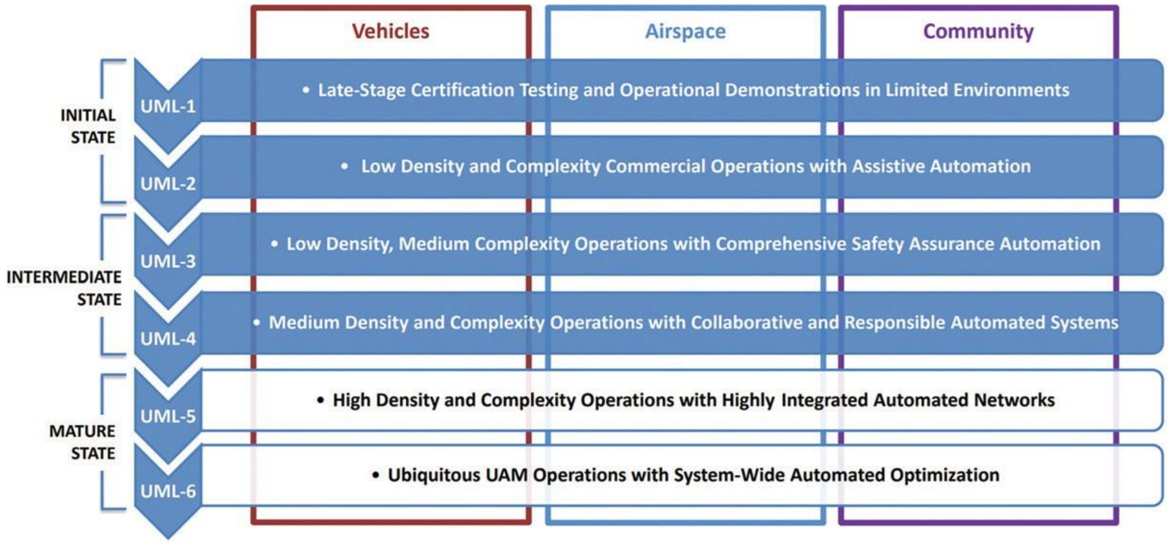

Figure 2 Urban air mobility maturity levels. *Source: NASA.*

NASA's Advanced Air Mobility National Campaign

In the United States, NASA's Aeronautics Research Mission Directorate (ARMD) launched the advanced air mobility working groups in Spring 2020 focused on enabling the UAM ecosystem through collaboration with public, private, and academic stakeholders. NASA has also developed a series of urban air mobility maturity levels intended to overcome vehicle, airspace, and community integration barriers from an initial to mature state (Fig. 2). NASA's *Advanced Air Mobility National Campaign* aims to improve UAM safety and accelerate scalability through integrated demonstrations through a series of ecosystem-wide challenges beginning in 2020. It is envisioned that the AAM National Campaign will support the United States. FAA in developing an approval process for UAM aircraft certification, develop: (1) flight procedure guidelines, (2) evaluate communication, (3) navigation and surveillance requirements, (4) define airspace operations management activities, and (5) characterize vehicle noise levels. The first testing opportunity in the National Campaign will focus on the testing of US developed aircraft and will include airspace operations management services to explore architectures and technologies needed to support future UAM safety and scalability of operations (Garrett-Glaser, 2019).

FAA's Unmanned Aircraft Systems (UAS) Integration Pilot Program (IPP)

In addition to the AAM National Campaign, the FAA's UAS Integration Pilot Program is helping the US Department of Transportation (DOT) develop new rules for unmanned aircraft (e.g., drones) that support more complex low-altitude operations by: (1) identifying ways to balance local and national interests related to drone integration; (2) improving communications with local, state, and tribal jurisdictions; (3) addressing security and privacy risks; and (4) accelerating the approval of operations that currently require special authorizations. Key goals of this initiative include establishing a dialog between local and national interests related to drone integration and providing actionable information to the US DOT on expanded and universal integration of drones into the National Airspace System. The IPP has funded nine lead participants that are evaluating a host of operational concepts including: package delivery, flights over people and beyond the pilot's line of sight, night operations, detect-and-avoid technologies, and the reliability and security of data links between pilot and aircraft (FAA, 2019). While the IPP has started this conversation, the industry still has not perfected the integration of unmanned systems for small, unmanned aircraft (aircraft that weigh less than 55 pounds on take-off) nor large UAS into routine operations. Leveraging emerging lessons learned from the IPP, in Summer 2020 the FAA released the UAM Concept of Operations (ConOps) v1.0 which presents an air traffic management vision to support initial UAM operations in urban and suburban environments. The ConOps provides an initial framework for evolving from initial low complexity and low frequency operations to more mature operations with increasing frequency and complexity.

EASA Regulatory Developments

Similar to the FAA, the EASA certifies, regulates, standardizes, investigates, and monitors air transportation for the European Union. In May 2017, EASA published UAS regulations. In January 2019, the European Union, outside of EASA, passed UAS regulations that guide UAS operations and licensing. In Summer 2019, EASA published a special condition for certification of small electric and hybrid VTOL aircraft. The regulation establishes two categories of aircraft: basic and enhanced. Basic aircraft certification standards will be used for personal and rural aircraft. Enhanced aircraft certification standards apply to aircraft used in commercial operations and flight over urban areas. The regulation allows for aircraft with a pilot on board, remotely piloted, or various degrees of autonomy (EASA, 2019). In Summer 2020, EASA released a means of compliance (MOC) publication with draft guidance for manufacturers of multirotor, lift-plus-thrust, and vectored thrust aircraft configurations. The document is intended to provide manufacturers guidance on how to comply with certification requirements.

ICAO Regulatory Developments

Internationally, ICAO regulates aviation safety, security, efficiency, regularity, and environmental protection for international air travel. In 2011, ICAO published a report that set standards for UAS airworthiness and licensing. However, laws regulating UAS vary by country. In an ICAO executive meeting in July 2019, UAM was presented by the United Arab Emirates as a high-level policy issue that required ICAO's input. ICAO determined that UAM poses a variety of challenges including lack of certification definitions and operational rules, lack of guidance to develop regulatory frameworks, gaps in existing information on unmanned systems, and a need for further research (ICAO, 2019). At present, international regulation on UAM is limited. Organizations including EASA and US-based ASTM International are working on developing airworthiness certifications for UAM and VTOL.

Air traffic management and public policy may need to evolve quickly to safely manage a growing number of new airspace users. Additionally, while many aviation authorities have emphasized national pre-emption of regulatory authority of the airspace, local and regional governments may argue for more local control over when and where urban air taxis fly. While many of these regulatory challenges have yet to be addressed, the policy environment will likely need to adapt quickly to emerging aviation technologies (e.g., electrification and automation) and new users of the airspace, such as UAM and small UAS package delivery.

Conclusion: Leveraging COVID-19 Medical and Sanitation Use Cases to Build Community Awareness

COVID-19 has presented a meaningful moment to demonstrate the potential of UAM and UAS, particularly in providing critical goods delivery and medical response. In May 2020, United Parcel Service began to expand its drone delivery program with CVS Health Corporation to delivery prescription medications to more than 135,000 residents in a Florida retirement community. In Ghana, California-based drone start-up, Zipline, began delivering critical medical supplies and COVID-19 test samples in Accra and Kumasi. In the United Arab Emirates and Indonesia, communities are using drones to spray disinfectant as part of a program to sanitize urban streets. In China, drones have been used to remind people to wear a facemask and to maintain social/physical distancing. These represent a handful of examples of how the COVID-19 pandemic has helped push UAS and UAM from the fringe to a potential strategy for emergency evacuation, response, and delivery of life saving equipment, tests, and medications. Although these examples are relatively limited, COVID-19 could be the moment that helps raise community awareness of this nascent aviation sector. Moving forward research on the potential impacts of UAM, coupled with prudent planning and implementation, are needed to balance commercial interests, technology innovation, and the public good.

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Biographies

Adam Cohen is a mobility futures researcher at Innovative Mobility Research Group at the Transportation Sustainability Research Center (TSRC) at the University of California, Berkeley. Since joining the group in 2004, his research has focused on innovative mobility strategies, including urban air mobility, vehicle automation, smart cities, last mile delivery, shared mobility, smartphone apps, and other emerging technologies. Adam has published numerous peer-reviewed journal articles and reports on innovative and emerging transportation technologies and the future of mobility. Adam also served three combat tours in support of Operation Enduring Freedom as a rated aviator. Adam's unique multidisciplinary background gives him unique insight into automation, electrification, landside and airside aviation issues, and the potential impacts of innovative and disruptive technologies. Previously, Adam worked for the US Department of Homeland Security (DHS) and the Information Technology and Telecommunications Laboratory (ITTL) at the Georgia Tech Research Institute (GTRI). His academic background is in city and regional planning and international affairs.

Susan Shaheen is a professor in the Department of Civil and Environmental Engineering and a research engineer with the Institute of Transportation Studies at the University of California, Berkeley. She is also Co-Director of the Transportation Sustainability Research Center at UC Berkeley. She was among the first to observe, research, and write about the changing dynamics in shared mobility and the likely scenarios through which automated vehicles could gain prominence. She was the policy and behavioral research program leader at California Partners for Advanced Transit and Highways, a Special Assistant to the Director's Office of the California Department of Transportation, and the first Honda Distinguished Scholar in Transportation at the Institute of Transportation Studies at UC Davis, where she served as the endowed chair until 2012. She has authored 73 journal articles, over 125 reports and proceedings, 18 book chapters, and co-edited two books. She has a PhD from UC Davis and an MS from the University of Rochester.

See Also

Equity Concerns in Transport; Mobility as a Service (MaaS); The Future of Air Transport; Shared Mobility: An Overview of Definitions, Current Practices, and its Relationship to Mobility on Demand and Mobility as a Service; TNCs and the Future of Taxi Public Transport; Sharing: Attitudes and Perceptions; Future Mobility: Attitudes and Perceptions

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