

Learning for deployment of Robotaxis at scale

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vti



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Kort sammanfattning

”Robotaxis” (automatiserade fordon SAE level 4) har redan implementerats på nyckelmarknader, framför allt i USA och Kina. Detta har visat både potentialen och utmaningarna med tjänster som använder denna teknik. I Europa ses delade elektriska CCAM-lösningar som en viktig möjliggörare för att uppfylla EU:s mål för minskade utsläpp av växthusgaser. Såväl på nationell som på EU-nivå har flera pilot- och demonstrationsprojekt genomförts, men ännu finns inga storskaliga implementeringar av robotaxitjänster på dessa marknader.

Den studie, som ligger till grund för rapporten, förenar två partner från vardera Sverige och USA, och har syftat till att förbereda den offentliga sektorn för storskalig implementering av automatiserade fordon i urban miljö genom att genomföra: Inventering av befintliga kommersiella implementeringar av flottor med robotaxis i städer i USA och Kina, och identifiering av lärdomar - från allmänhet, operatörer, beställare, beslutsfattare – att beakta vid kommersiell implementering av robotaxis i Europa, med speciellt fokus på Sverige.

Metoder som använts inkluderar intervjuer med stakeholders involverade i befintliga implementeringar; workshops; analys av data, media, genomgång av litteratur, samt egna erfarenheter av att använda robotaxitjänster i USA (främst San Francisco) och Kina. Utifrån dessa ges rekommendationer för kritiska faktorer att beakta vid storskalig implementering av robotaxitjänster i Europa, speciellt i Sverige.

Nyckelord

Robotaxi, Lessons learned, självkörande fordon, autonom körning, kommersiell implementering, kollektivtrafik, affärsmodeller, USA, Kina.

Abstract

“Robotaxis” (SAE level 4 automated vehicles) have already been deployed in key markets worldwide, most notably in the United States and China. This has demonstrated both the potential and challenges of services using this technology. In Europe, shared electric CCAM solutions are seen as one important enabler to meet EU’s green-house gas reduction target. While national agencies, as well as EC have funded several CCAM pilot and demonstration projects, there are to-date no large-scale implementations of robotaxi services in the region.

The study which is reported here involved a new constellation of partners and aimed to prepare the public sector for large scale deployment of automated vehicles in urban areas by: Taking stock of the commercial operation of robotaxi fleets that have already been deployed in cities in the United States and China, and by identifying “lessons learnt” from the public, operators, and administrators to be applied to the planning for commercial implementation of robotaxis in Europe and Sweden in particular.

Methods used included interviews with stakeholders related to existing deployments, workshops, analysis of data, media and literature reviews, hands-on experience using robotaxi services in USA (primarily San Francisco) and China; leading to recommendations regarding critical factors to consider for the large-scale deployment of robotaxi services in Europe, with a focus on Sweden.

Keywords

Robotaxis, lessons learned, self-driving vehicles, autonomous driving, commercial implementation, public transport, business models, USA, China.

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Summary

Robotaxis – driverless vehicles operating as taxi services – have already moved beyond pilot projects and into commercial deployment, particularly in the United States and China. This report summarizes a project intended to prepare the public sector in other places for the potential large-scale implementation of automated vehicles in respective urban environments. The project, funded by the Swedish Innovation Agency, Vinnova, focused on analyzing existing commercial robotaxi operations in major U.S. and Chinese cities, identifying lessons learned from these deployments, and evaluating their implications for future implementations in Europe, with a particular emphasis on Sweden.

The study was based on extensive information research, interviews with stakeholders from the U.S., China, Europe, and Sweden, as well as focus group discussions with citizens in California. Insights from the U.S. and Chinese experiences were analyzed in light of the expectations, targets, and concerns expressed by Swedish stakeholders.

Swedish respondents, like many of their European counterparts, emphasized that robotaxis should contribute meaningfully to societal objectives rather than merely serving as a technological novelty. Among the key goals identified were supporting climate neutrality targets, improving traffic efficiency, reducing the overall number of vehicles on the road, and enhancing the financial sustainability of public transport. There was a strong consensus that robotaxis should complement, not compete with, public transportation systems. At the same time, stakeholders highlighted the challenge of balancing these societal ambitions with the pursuit of industrial and economic benefits.

Based on these perspectives, the report explores two fundamental questions: What lessons can be drawn from existing commercial deployments? And what critical knowledge gaps remain before robotaxis can be successfully integrated into European mobility ecosystems?

One of the most important dimensions is safety and security. The operational safety of robotaxi services must be at least on par with industry leaders such as Waymo. Early involvement of first responders is essential to ensure that automated vehicles can properly recognize and respond to emergency situations. Furthermore, robust reporting mechanisms for incidents such as vehicle immobilizations are necessary to identify and address potential weaknesses. The development of leading indicators for safety hazards, leveraging vehicle sensors and onboard systems, is another key recommendation. However, significant gaps remain in understanding the broader impact of robotaxis on traffic safety at the city or regional level, as well as in developing reliable methods to quantify and assess these effects.

Integration into the wider mobility system, particularly public transport, represents another critical challenge. Around-the-clock availability is often cited as a potential advantage of robotaxis compared to conventional transit services. Yet, current deployments remain too limited in scale to demonstrate any measurable shift in mobility behavior. Future efforts must address questions such as how to design services that genuinely move more people efficiently, how to create offerings that function as complementary solutions, especially in rural areas or during off-peak hours and how to prevent robotaxis from exacerbating congestion or parking challenges.

From a business perspective, one of the clearest findings is that no profitable robotaxi business models currently exist, nor have any been documented. Small- to medium-scale programs have so far done little to reveal the real implications of eventual large-scale deployments because they fail to produce sufficient economic and societal impact. Developing viable operating models for the European, and specifically Swedish, context remains an urgent priority, as does identifying strategies for achieving the critical user base required to sustain operations. Preliminary estimates suggest that a market of at least 500,000 inhabitants may be necessary for robotaxi services to be economically viable.

Finally, the role of cities in enabling successful deployment cannot be overstated. High levels of municipal involvement are consistently mentioned as a prerequisite for scaling up robotaxi operations.

Cities and transport authorities must begin by clearly defining the outcomes they seek to achieve and assessing how robotaxis can contribute to these goals. Early and sustained collaboration between municipalities, public transport agencies, and industry operators is essential. Practical considerations such as curbside management and the allocation of pick-up and drop-off zones require proactive planning. An unresolved issue is whether regulatory frameworks should extend beyond vehicles to encompass the entire robotaxi service model, and if so, how such regulations should be structured.

The report concludes with detailed recommendations for municipalities, regulators, public transport authorities, industry players, and research organizations. Among these, the development of sustainable business models emerges as a critical priority requiring close cooperation among all stakeholders. The lessons drawn from existing deployments provide a valuable starting point, but significant gaps in knowledge and practice remain before robotaxis can fulfill their promise as an integral component of future urban mobility systems.



Figure 1: Inside a Pony.ai robotaxi [Pony.ai Media Kit]

Preface

This report summarizes the Vinnova-funded project “Learning for Robotaxi Deployments of Scale” and aims to present learnings from both current and past robotaxi programs in the United States and China that Europe, and Sweden in particular, can draw upon. Its objective is to discern success factors and obstacles, thereby assisting future deployments by providing stakeholders insights on anticipated outcomes and thus helping in the preparation for the introduction and utilization of this technology within Europe.

The study was undertaken January-August 2025, and it was supported by Pony.ai (in California) and Zeekr Technology Europe (in Gothenburg). Activities were undertaken in the US, in China, in Sweden and Europe.

The authors wish to express their gratitude to the individuals who provided invaluable insights through interviews, focus groups, discussions, shared ride experiences, and their own research. They are listed without affiliation as they often shared their personal observations and opinions, which makes this report even more valuable. In alphabetical order, those who gave permission to include their name here are: Marc Amblard, Caroline Askerud, Michelle Avary, Abubaker Azam, Bob Brydia, Kristine Bull Sletholt, Pat Burt, Henriette Cornet, Terra Curtis, Angus Davol, Mehment Inönü, Mikael Ivari, Randy Iwasaki, Frankie James, Sylvia Kurpanek, Adam Laurell, Yongsun Lee, Xiang Li, Kai Liu, Yandeng Long, Christian Monstein, Nicolas Morael, Jarvis Murray, Mattias Näsström, Per Nyrenius, Makanani (Nani) Randall, Stacey Randecker, Andreas Reschka, William (Billy) Riggs, Steve Shladover, Tonxu Tan, Johanna Thidell, Jeffrey Tumlin, Bryant Walker Smith, Ying Wang, Jens Weitzel, Alex Yan, Simon Yan. And there are many more, who we also thank sincerely and respect their anonymity.

Göteborg, October 2025

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De slutsatser och rekommendationer som uttrycks är författarens/författarnas egna och speglar inte nödvändigtvis myndigheten VTI:s uppfattning./The conclusions and recommendations in the report are those of the author(s) and do not necessarily reflect the views of VTI as a government agency.

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Jonas Jansson, VTI.

Acronyms

ADS	Automated Driving System
AV	Automated Vehicle
CCAM	Connected, Cooperative Automated Mobility
CPUC	California Public Utility Commission (California)
DMV	Department of Motor Vehicles (California)
DOT	Department of Transportation (United States)
EC	European Commission
ECAVA	European Connected and Autonomous Vehicle Alliance
FMVSS	Federal Motor Vehicle Safety Standard
FSD	Fully Self Driving (Tesla)
ICV	Intelligent Connected Vehicle
MIIT	Ministry of Industry and Information Technology (China)
MOT	Ministry of Transport (China)
MPS	Ministry of Public Security (China)
NHTSA	National Highway Traffic Safety Administration (United States)
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PT	Public Transport
PTA	Public Transport Authority
PTO	Public Transport Operator
R&I	Research and Innovation
SFO	San Francisco International Airport
SRIA	Strategic Research and Innovation Agenda (CCAM Partnership)
TAM	Total Accessible Market
V2I	Vehicle to Infrastructure

1. Introduction & background

Over the last five years, robotaxis, i.e. L4 automated vehicles operating as taxi services, have shown a remarkable evolution from isolated pilot projects into commercial offerings deployed in some of the key markets worldwide, most notably in the United States and China. This has demonstrated both the potential and the challenges of services using this technology. While there have been positive outcomes in terms of technological advancement and service efficiency, negative aspects such as regulatory conflicts, safety concerns, and questions about public acceptance have also emerged.

Simultaneously, Sweden, alongside several other European nations, is actively pursuing automated mobility options, in particular the use of shared vehicles including robotaxis, to reach enhanced safety, transportation equality, and environmental sustainability, traffic efficiency, competitiveness and technological advancements. Over time, a recognition of the complexity of introducing highly automated vehicles into the European transport system has grown. CCAM, connected, cooperative and automated mobility, is considered a multifaceted field requiring the involvement of a wide range of stakeholders, going across disciplines and beyond the initial focus of technology and vehicles.

This view is mirrored by the establishment of coordinated ecosystems for self-driving vehicles across Europe as well as within certain Member States. Such ecosystems typically involve collaboration between industry, government, and research organizations through partnerships (e.g., the CCAM Partnership at EU level) and alliances. It also aims to unify policies and standards and provide strategic R&I funding via Horizon Europe for various aspects of CCAM, including pilots and cross-border tests.

Shared CCAM services, such as robotaxis, are seen as enablers for mobility solutions that could lower urban emissions, increase traffic safety, reduce car dependency, improve equitable access to transport, and stimulate innovation, industrial competitiveness, and growth.

While societal considerations are in focus, competitiveness of the European industry is another key concern of the European Commission (EC). Recognizing the fierce rivalry in the global automotive industry, the EC has presented an Action Plan for the sector's competitiveness in March 2025¹, with items identified to ensure a sustainable and strong automotive industry in Europe. The role of innovation and digitalization is emphasized and specifically mentions large-scale cross-border automated driving.² A European Connected and Autonomous Vehicle Alliance (ECAVA) is being set up, aiming to bring together Europe's automotive stakeholders to help deploy (and scale up) the technology. Joint public-private investments of around €1 billion backed by the Horizon Europe Programme over the 2025-2027 period are anticipated to support the actions.³

The drive for large-scale deployments in Europe, coupled with the competitive pressure, underscores the critical need to comprehend the factors influencing the implementations of automated vehicles into existing transportation systems, such as the recent robotaxi developments in other parts of the world, most notably the United States and China.

Despite the significant variations in conditions and driving forces across regions, it remains imperative to look into these factors to facilitate successful commercial operations.

¹ Press statement VDL 3/3 2025 downloaded from:

https://ec.europa.eu/commission/presscorner/api/files/document/print/en/statement_25_656/STATEMENT_25_656_EN.pdf

² European Commission: Factsheet – Action Plan on the future of the automotive sector, 5 March 2025; downloaded from: https://ec.europa.eu/commission/presscorner/detail/en/fs_25_637

³ <https://www.connectedautomateddriving.eu/blog/ec-action-plan-for-automotive-industry/>

This report seeks to provide insights into what large-scale implementation of shared self-driving vehicles (robotaxis) looks like in practice to provide important insights to Swedish and European decision-makers and stakeholders.

2. Methodology

This study adopted a multi-faceted approach to research facts about robotaxi deployments, encompassing information research, stakeholder interviews and focus groups. Details can be found in Annex 1.

2.1. Information research

Comprehensive research for information about global robotaxi deployments, with a specific emphasis on the United States and China, was undertaken. While there are numerous articles about vehicle related aspects such as technology, the limited number of commercial robotaxi deployments is reflected in a scarcity of publicly available studies involving individuals who have utilized such services. A similar shortage is noted for studies of stakeholders on community level that have experience in the integration of robotaxis into their transport system. Consequently, user experiences are predominantly anecdotal rather than statistically robust. However, the numerous experts consulted for this study indicated that such specific insights and narratives can provide a reasonably accurate portrayal of the preferences and dislikes of robotaxi users. They also provided examples of considerations that should be considered in future deployments. Therefore, the stakeholder interviews and focus groups play a critical role in the findings of this study, potentially more than the facts and information research conducted by the team.

The information researched through those channels formed the content presented in chapter 4.

2.2. Stakeholder interviews

Both online and in-person interviews were conducted in the United States, primarily in California, as well as in China and Sweden. The participants included a diverse range of individuals from municipalities and administrations, vehicle providers, operators/service providers, and researchers. The interviews were structured to comprehensively explore various facets of robotaxi implementation, encompassing the underlying motivations, processes/procedures involved, the significance of partnerships, the public's response to the services, and any areas of robotaxi deployment that could be considered having been overlooked. In this regard, the interviews conducted in the United States and China concentrated on the lessons derived from robotaxi deployments, while in Sweden, they primarily focused on the anticipated expectations of stakeholders regarding the eventual arrival of those vehicle fleets in their locations.

The stakeholder interviews largely formed the content presented in chapters 4 and 5.

It was determined to conduct focus groups of members of the public (i.e. robotaxi users and also non-users) to provide a broader perspective through a workshop-like discussion and thereby gain insights into citizens' views (positive and negative) of this form of transportation. Although not statistically representative, these mobility users contributed diverse and valuable insights to the study. Two focus groups were conducted at the end of February 2025, one in San Francisco and the other in Palo Alto. In addition, open and informal discussions were led within a small study group of during a fieldtrip to experience robotaxi services in Beijing, Shenzhen, and Guangzhou in August 2025 (although it needs to be pointed out that those individuals have all some involvement with robotaxis and are therefore not layperson users, however their observations and opinions are considered very valuable for this study).

The project leaders analyzed information research, stakeholder interviews, and focus groups to draw conclusions and recommendations. Draft insights were developed and shared with stakeholders to gather diverse perspectives and enhance findings. The project team and interview partners reviewed draft versions of the report to comment on the findings. The project team also paid attention to other projects' presentations at conferences or publications to complement and cross-check the final outcome.

3. Robotaxi state of play

3.1. Robotaxi basics

3.1.1. Definition: robotaxi and automated shuttle

A robotaxi is a L4 automated (“self-driving”) vehicle that operates as a ride-hailing or taxi service without a human driver. Users typically hail them through an app, similar to traditional ride-sharing services like Uber or Bolt, and the robotaxi then transports them to their desired destination autonomously. *Robotaxis* are generally designed for individual or small group transportation, offering on-demand, point-to-point service. They aim to reduce operating costs by eliminating the need for a human driver and are envisioned as a key element of the future mobility spectrum, especially in urban areas. There is also a general belief that incidents and crashes induced by driver errors will be eliminated, thus enhancing safety.

In contrast, *automated shuttles* are typically larger, designed for shared, collective transportation of multiple passengers on fixed, pre-defined, routes, such as campus circulators or “first-mile/last-mile” connections. Current shuttles typically operate at comparatively low speed due to technical limitations. Notably, automated shuttles do not hold a substantial presence in the United States, particularly when compared to the robotaxis deployed by Waymo and Cruise or the ones anticipated by Tesla and Zoox. In China and Europe, there are however several implementations of those rather basic vehicles so that those will be tangentially discussed in this report in order to compare and contrast robotaxis to them.

In that context, it is to say that the focus of this present study has been robotaxis which are considered to be technologically more advanced and potentially having a broader range of applications to bring great change to transportation behavior and businesses. But to provide context, it is still worth mentioning US deployments of shuttles such as Navya and EasyMile. For instance, Navya, through its Beep platform, has been operating up to now 22 shuttles in locations like Lake Nona, Florida, and Peachtree Corners, Georgia. Similarly, EasyMile had a nine-shuttle project at the Colorado School of Mines. Atlanta is preparing for self-driving shuttle services to be operated by Beep during the FIFA World Cup 26TM, when some of the matches will be hosted in the city⁴.

3.1.2. Technology

Self-driving automobiles integrate sophisticated technology components that are collectively described as the “AV stack”. This comprises an array of sensors for environmental perception, powerful computing platforms for real-time data processing, and advanced software algorithms for localization, path planning, and vehicle control. These modules work in concert to allow the vehicle to perceive, understand, and navigate its surroundings autonomously, i.e. largely without human interference.

The readiness of this technology is obviously essential for the successful deployment of robotaxis. Operators need to have confidence in their systems’ safety and functionality but also effectively convey that assurance to local authorities and certainly its users. This challenge is compounded by the current lack of commonly agreed-upon industry standards, in particular for autonomous vehicle safety. Consequently, a successful and practical launch of robotaxis necessitates close collaboration between manufacturers, operators, and local regulatory bodies to establish and implement appropriate regulations and safety protocols.

A significant ongoing debate revolves around the precise technological components necessary for truly safe and practical robotaxi operation. One key area of contention is the optimal sensor suite. While many developers favor a comprehensive all-in approach, integrating lidar, radar, cameras, and

⁴ <https://www.newsweek.com/autonomous-shuttles-are-popping-across-america-time-world-cup-2084815>

ultrasound, some, notably Tesla, primarily rely on cameras. Although the ultimate victor in this technological arms race remains to be seen, most experts concur that a robust system will likely require a combination of several solutions – lidar, radar, cameras, and precise mapping / localization – leveraging sensor fusion technology. This multi-modal approach is deemed essential due to the inherent limitations of individual sensor types and their complementary strengths, providing a more holistic and reliable perception of the environment. However, the cost level of such a system provides a key challenge that needs to be tackled.

Another crucial technology-related question concerns the role and extent of artificial intelligence. More traditional automotive players express apprehension about using AI in critical safety applications, such as direct vehicle control. However, it is also becoming increasingly clear that achieving truly driverless operation without human intervention may be impossible without sophisticated AI. AI algorithms are vital for processing vast amounts of sensor data, enabling real-time decision-making, path planning, and adapting to unforeseen circumstances, capabilities far beyond what rule-based techniques in traditional automotive control systems can achieve.

Finally, the role of infrastructure is a vital consideration, encompassing the necessary communication technology and potentially machine-readable road markings or signage to guide driverless vehicles. While the debate continues regarding the exact level of communication infrastructure required, particularly given the significant implementation costs and timelines, it is noteworthy that all known robotaxi deployments currently rely on some form of communication with a central control center. This remote link is crucial for monitoring vehicles, providing human assistance in unexpected situations (such as unforeseen road work or detours), and enabling emergency interventions if called upon by passengers pushing an emergency button in the vehicles, or when commanding a safe stop. Such remote monitoring and interference capabilities are typically mandated by regulators, highlighting their importance in ensuring safety and operational integrity during these early stages of robotaxi deployment. It is worthwhile mentioning that remote operations for automated vehicles in itself is a topic of discussion and research from a variety of angles such as organizational and legal issues. Some companies make great efforts to emphasize that they are not performing “remote driving”, others are quieter about this particular topic or even admit that a human might take over control under certain circumstances, i.e. when the automation system comes to the end of its capabilities in a certain traffic situation.

3.1.3. Implementation process and regulation

Integrating robotaxis into a city’s existing transportation system requires a multi-faceted approach. First, robust regulatory frameworks are essential to address safety, liability, and to give operational guidelines, necessitating collaboration among the public sector (e.g., national / regional transportation departments, municipalities, public transport / utility agencies, local law enforcement and first responders), and robotaxi operators (e.g., Waymo). Second, dedicated infrastructure adjustments, such as enhanced digital mapping, smart traffic signal integration, and potentially designated pick-up/drop-off zones may be necessary to optimize the efficiency and interaction with traditional traffic, involving city planning departments, public works, traffic engineers, and again the robotaxi companies themselves. Third, the success of a robotaxi service will highly depend on public acceptance and trust. Awareness and education campaigns as well as initial pilot programs that demonstrate the benefits of autonomous mobility are ways to involve the public and enablers for building the essential trust. Such efforts can be led by robotaxi companies, city officials, community organizations, and independent advocacy groups (such as representatives for senior citizens, the visually impaired, and low-income individuals).

By adhering to these steps and engaging the relevant stakeholders, it becomes clear that the successful integration of robotaxis into urban environments relies on a fundamental principle: aligning

deployment with the unique requirements of each city or location. That is why studying existing practical implementations provides valuable insights.

3.2. Select robotaxi deployments in the United States

3.2.1. Waymo

Waymo, a subsidiary of Alphabet, is a prominent player in the robotaxi technology industry. As of May 2025, the completely driverless robotaxi service Waymo One was operating in Phoenix, San Francisco, Los Angeles, and Austin. Late that spring 2025, Waymo's services expanded south of San Francisco to encompass major parts of Silicon Valley, including Menlo Park, Palo Alto, and Mountain View. Further expansions to San Jose are anticipated. A Miami rollout has commenced with testing in 2024, and a launch to riders is planned for 2026. Additionally, Waymo is expanding to Atlanta and Washington, D.C. through 2026. Internationally, Waymo has established plans for deployments in Tokyo, and there are discussions about a future launch in London. Parts of Manhattan in New York City is apparently also being mapped by Waymo to assess and potentially prepare robotaxis services for The Big Apple.



Figure 2: Waymo robotaxi in San Francisco [Sven Beiker].

In Phoenix, San Francisco, and Los Angeles, riders utilize the proprietary Waymo One smartphone app. In Austin and soon Atlanta, rides are exclusively hailed through the Uber app. Notably, all these deployments are conducted without the presence of human personnel on board.

Waymo's fleet has experienced consistent growth as ridership has increased. Currently (spring 2025), the fleet comprises approximately 1,500 Jaguar I-PACE battery-electric SUVs equipped with the Waymo Driver autonomy system, which enables the vehicles to operate without human interference. This fleet provides approximately 250,000 paid rides per week. A recently established assembly plant

in Mesa, Arizona, (in partnership with Magna International) will facilitate the integration of Waymo's AV stack (hardware and software) into vehicles. Waymo's strategic objective is to scale its U.S. fleet to approximately 3,500 vehicles by the conclusion of 2026.

Waymo's public statistics⁵ show that its autonomous vehicles have accumulated over 80 million kilometers in driverless mode, primarily in Phoenix. The data suggests improved safety compared to human drivers. In Phoenix and San Francisco Waymo reported significantly lower driverless crash rates: 83% fewer airbag deployment crashes, 81% fewer injury-causing crashes, and 64% fewer police-reported crashes. Comparisons for Los Angeles and Austin were not statistically significant due to lower mileage.

The experiences collected with Waymo, whether as a user, municipality, or regulator, constitute the majority of the content of this study in relation to the United States. The project team extensively tested the Waymo service in San Francisco and Los Angeles.

3.2.2. Other robotaxi companies in the United States

The robotaxi landscape in the United States is rapidly evolving, with several key players aiming to capture this new opportunity in the transportation field. The following companies can be considered as potential competitors to Waymo:

Cruise, the autonomous vehicle company majority-owned by General Motors, faced significant setbacks in late 2023 that led to the cessation of its robotaxi operations in 2024. After expanding driverless services in San Francisco, Austin, Houston, and Phoenix, Cruise was seen as a very close contender to Waymo, but then encountered a critical incident in October 2023 in San Francisco where one of its robotaxis dragged a pedestrian who had been struck by a human-driven vehicle.

This event, coupled with allegations of withholding information, led to the suspension of Cruise's permits in California and a nationwide halt to operations. Despite initial attempts to resume limited manual driving and testing in select cities later in 2024, GM announced at the end of that year that it would no longer fund Cruise's robotaxi development, opting instead to integrate Cruise's technology into GM's advanced driver-assistance systems like Super Cruise for personal vehicles. This decision, expected to save GM over \$1 billion annually, marked a significant pivot away from a dedicated robotaxi service, effectively ending Cruise's ambition to operate a large-scale commercial robotaxi fleet in 2025. It may be worthwhile mentioning that some of this study's project team members acquired extensive experience utilizing Cruise's robotaxis prior to the events in October 2023.

Zoox, an Amazon subsidiary, is notable for its purpose-built, bi-directional, all-electric robotaxi. Unlike many competitors that adapt existing vehicles, Zoox has designed its vehicle from the ground up for autonomous ride-hailing, featuring a symmetrical design, no steering wheel, and facing seats. The company received approval to begin testing with passengers in California in 2023 and the vehicles have been tested in the San Francisco Bay Area (Foster City) and Las Vegas, Nevada for several years now. Zoox has an assembly plant in Hayward, CA, with a capacity to produce over 10,000 robotaxis annually, and plans to launch services in Las Vegas, San Francisco, Austin, and Miami in the 2025-2026 timeframe. Advanced public testing of driverless taxis, without human safety personnel on board, have started in Las Vegas and San Francisco in early 2025. This present study's project team had the opportunity to test the Zoox service in San Francisco in August 2025.

⁵ <https://waymo.com/safety>

Pony.ai is a global autonomous driving technology company with operations in both California and China. In the U.S., Pony.ai has been actively testing and developing its robotaxi technology, accumulating millions of kilometers in autonomous road testing. They focus on a multi-sensor fusion approach (lidar, cameras, radar) and emphasize safety with redundant systems. Uber has allegedly been in talks with Pony.ai for a potential acquisition of its U.S. arm⁶ and already partners with investors to deploy its robotaxis on the Uber platform, with initial pilots expected in the Middle East. As of summer 2025, Pony.ai does not operate a public robotaxi service in the United States. However, it does operate a public robotaxi service in several Chinese cities, as detailed in the subsequent section. Pony.ai is a collaborator on this study and early versions of its robotaxi demonstrators were tested by the project team at the U.S. headquarters in Fremont, California.

May Mobility focuses on deploying automated shuttles and robotaxis for specific transit needs, often in partnership with cities and transit agencies. They emphasize that their technology allows vehicles to learn and adapt in real-time to unexpected situations. May Mobility has active deployments in various U.S. cities: Peachtree Corners, GA (driverless), Arlington, TX, Detroit, MI, Miami, FL, Martinez, CA. They recently partnered with Uber and Lyft to integrate their robotaxis onto these ride-hailing platforms, with plans to deploy thousands of vehicles. The project team tested the May Mobility service in Martinez, CA in February 2025

What about Tesla?

Tesla pursues an approach to robotaxis centered on its Full Self-Driving (FSD) software integrated into its existing vehicle lineup (primarily Model Y for early deployments). It is noted that the system employs exclusively cameras (as opposed to the laser-radar-camera combination employed by the majority of other robotaxi companies) and adopts an end-to-end AI approach (rather than the perception-prediction-planning modularity utilized by most competitors). In October 2024, Tesla CEO Elon Musk unveiled 20 "Cybercabs" at a "We, Robot" event. These AI-powered vehicles were shown without steering wheels or pedals, with Musk promising they would be available by 2026 for under \$30,000. By April 2025, a report revealed that 300 test operators were already driving in Austin as part of "Project Rodeo" to accumulate critical miles. In May, Musk announced that the initial Austin tests would be limited to the "safest" parts of the city, with vehicles avoiding complex intersections.

The company officially launched its limited robotaxi service for well-known users in Austin in June 2025, a month after facing competition from companies like Waymo. Rides were offered in Model Y SUVs with safety personnel present and at a flat fee. By July, Tesla was already trying to expand to Arizona, applying to test and operate vehicles with and without a driver. Expansion to the San Francisco Bay Area in July included a person in the driver's seat (in Austin only on the front passenger seat), also because the company would not have regulatory approval to operate otherwise.

Many dismissed and ridiculed Tesla's robotaxi launch, but some experts, including one author of this report, argue that Tesla's robotaxi ambitions should not be judged by what it is today but by what it can be in 2-3 years from now.

3.2.3. Extended value chain

Beyond the well-known robotaxi developers, several other companies play crucial roles in enabling and expanding autonomous mobility services. These are key players in the value chain and often fall into two categories: those that manufacture the specialized base vehicles designed to be retrofitted with autonomous driving systems, and those that operate the robotaxi fleets as a service provider, even if they do not develop the core autonomous technology. This collaborative ecosystem is vital for the eventual scalability and widespread adoption of robotaxis.

⁶ <https://techcrunch.com/2025/06/26/travis-kalanick-is-trying-to-buy-pony-ai-and-uber-might-help/>

One example in vehicle manufacturing is **Zeekr**, a premium electric vehicle brand within the Chinese automotive group Geely. Zeekr has partnered with Waymo to develop purpose-built, all-electric autonomous ride-hailing vehicles for Waymo One in the United States. These vehicles, designed from the ground up for autonomous operation, prioritize passenger experience with features like spacious interiors, flat floors, and easy access, showcasing a dedicated approach to robotaxi vehicle hardware. The Zeekr vehicle, integrated with Waymo's autonomous technology, was unveiled in November 2022. Waymo and Zeekr began working on the platform in 2021. While the exact date for widespread public operation of the Zeekr vehicle in Waymo's fleet is not explicitly stated, Waymo has been testing the vehicle already in public and apparently plans to build Zeekr vehicles in partnership with Magna International at the factory in Mesa, Arizona, mentioned in the previous section. Zeekr is also a collaborator on this study.



Figure 3: Zeekr vehicle for Waymo robotaxi service [Source: Waymo].

On the operational side, companies like **Transdev** play a critical role. While Transdev does not get involved in the development or production of the autonomous vehicles themselves, it specializes in managing and operating vehicle fleets, including those without a driver. For example, Transdev has been a key partner for Waymo for several years, handling various aspects of their robotaxi operations in cities like Phoenix, San Francisco, Los Angeles, and Austin. This includes depot management, vehicle preparation, charging/fueling, maintenance, customer support, and even assisting with regulatory compliance and workforce management. These partnerships allow robotaxi developers to focus on refining their core technology, while experienced transit operators like Transdev leverage their expertise in logistics, fleet management, and public transportation to ensure smooth, efficient, and safe daily robotaxi services. **Beep** would be in a similar category with a variety of shuttle vehicles operating in various locations the United States.

How does Waymo's service compare to Uber and Lyft?

In November 2024, Waymo's market share in San Francisco was 22%, the same as Lyft's, while Uber held a 55% share.ⁱ Waymo's growth has come at the expense of both Uber and Lyft, who lost a low double-digit percentage of their market share, though the loss was more significant for Lyft, which gave up one-third of its share compared to Uber's one-sixth.

Despite having longer wait times than Uber and Lyft due to a smaller number of vehicles, Waymo's "superior product" has attracted riders and is said to be consistently more expensive than Uber and Lyft. A recent study by Obi, an aggregator app for hailing options, claims that "Waymo rides cost 41% more than Lyft and 31% more than Uber on average when comparing pricing at the same time and across the same routes."ⁱⁱ It should be noted that such studies are controversial and at times anecdotal. Research for this report found similar comparisons to the ones from Obi.

A survey of riders in Los Angeles, San Francisco, and Phoenix found that 70% of Waymo users preferred a driverless car, with some willing to pay a premium.ⁱⁱⁱ Such willingness to pay more, even in light of longer wait times, suggests a preference for the driverless experience. Waymo also has a higher customer retention rate than both Uber and Lyft.ⁱⁱⁱ

For further information, the forthcoming study by Riggs and Karkoski at the University of San Francisco is highly anticipated by the.

i. <https://x.com/aleximm/status/1867257473671082356>

ii. <https://www.documentcloud.org/documents/25973106-obi-waymo-61125/>

iii. <https://www.earnestanalytics.com/insights/waymo-retention-leads-uber-lyft-as-it-expands-coverage-area>

Once considered disruptive, ride-hailing companies like **Uber and Lyft** are now also beginning to play an important role in the emerging robotaxi ecosystem. Some of them had at some point or might still have their own inhouse self-driving car programs (e.g. Uber ATG, Lyft Level 5). They can be considered as demand generators and for them robotaxis provide a lower operational cost and can fill driver shortage gaps.

Recently, several partnerships among leading robotaxi companies could be observed as the ride-hailing experts want to secure the future of "their" business and also provide necessary scale to the robotaxi leaders. Notable partnerships are Uber and Waymo in Austin and Atlanta⁷, Lyft and Baidu in Germany and the UK⁸, Pony.ai and Uber in the Middle East⁹.

3.3. Select robotaxi deployments in China

China presents a dynamic and competitive environment for autonomous vehicle development, particularly with robotaxis (in parallel to several notable automated truck deployments). Several major Chinese cities, including Beijing, Shanghai, Guangzhou, Shenzhen, and Wuhan, have been at the forefront of issuing robotaxi testing and operational permits. These cities have established zones with advanced infrastructure, such as communication of traffic light phase and time etc., where intelligent connected vehicles (ICV) can be run and demonstrated. Local regulations typically encompass various aspects, including vehicle registration, insurance requirements, data security, and accident liability.

Companies frequently collaborate with local vehicle developers, such as Geely and BYD, to produce AV-ready models at scale. By 2025, cities like Beijing and Wuhan had granted permits for fully driverless rides to the public under certain operational conditions. Notably:

- Beijing's autonomous driving regulations, effective April 1, 2025, establish comprehensive rules for AV safety, traffic management, and infrastructure support.

⁷ <https://waymo.com/blog/2024/09/waymo-and-uber-expand-partnership/>

⁸ <https://techcrunch.com/2025/08/04/lyft-and-chinas-baidu-look-to-bring-robotaxis-to-europe-next-year/>

⁹ <https://investor.uber.com/news-events/news/press-release-details/2025/PONY-AI-Inc--and-Uber-Announce-Strategic-Partnership-to-Advance-Autonomous-Mobility/default.aspx>

- Shenzhen has enacted some of the most advanced city-level AV legislation, including legal frameworks for commercial robotaxi operations.

As of summer 2025, China's robotaxi industry is experiencing rapid advancement, with several key players emerging: Baidu, Pony.ai, WeRide.

3.3.1. Notable robotaxi companies in China

Baidu Apollo Go operates fully driverless robotaxi services in more than 10 Chinese cities, including Beijing, Shenzhen, Guangzhou, Chongqing, and Wuhan. Over 1,1 million paid rides were provided in Q4/2024. According to press articles from mid-2024, Apollo Go is aiming to become profitable by 2025. In May 2025, media reports that Apollo Go considers 2025 an important year for international expansion and mentions plans for introduction into Switzerland and Turkey¹⁰ as well as Germany through a partnership with Lyft⁸. In 2024 Baidu Apollo Go deployed 400 autonomous vehicles in Wuhan, completing over 6 million trips. Wuhan is said to have diverse road conditions, and the service covers 750 km of roads citywide, including the international airport. Users can access Apollo Go through Baidu Maps or the “Apollo Go” app. The project team tested the Baidu Apollo Go service in Beijing.

Pony.ai, the California – Chinese company already discussed before, operates 300 robotaxis in China and plans 1,000 more by 2026; it maintains a joint venture with Toyota China. Pony.ai was the first company authorized to operate fully driverless, paid robotaxi services in Shenzhen's Nanshan District, and holds licenses for similar services in Beijing, Guangzhou and Shanghai. Pony.ai has launched autonomous driving services in Guangzhou, connecting downtown areas with major transportation hubs like Guangzhou Baiyun International Airport and Guangzhou South Railway Station. The company aims to deploy 1,000 autonomous taxis across China by the end of 2025, aiming for profitability as it scales up operations. Furthermore, Pony.ai and Uber announced in spring 2025 a strategic partnership to advance autonomous mobility. As mentioned before, Pony.ai is a collaborator on this study and the China staff also provided input to this report. The project team extensively tested the Pony.ai service in Beijing, Shenzhen, and Guangzhou.

WeRide has ran large scale pilots in Beijing where it has also initiated fully unmanned commercial robotaxi operations. It is headquartered in Guangzhou, where in spring 2025 it introduced a 24/7 robotaxi service network in the city center. There are also robotaxi operations in Shenzhen. The company has furthermore expanded internationally, operating services in cities like Abu Dhabi (in partnership with Uber) and is planning further expansion into Europe. Uber and WeRide have indicated that they plan to bring such service to 15 more cities in the next 5 years. WeRide is also expanding its fleet in China, focusing on technological advancements and cost reductions. The project team extensively tested the WeRide service in Beijing and Guangzhou.

¹⁰ <https://themunicheye.com/baidu-robotaxis-switzerland-turkey-launch-21148>



Figure 4: Pony.ai robotaxi in Shenzhen, picking up the study team for a test ride [Sven Beiker]

3.4. Legal situation of driverless vehicles in public

3.4.1. United States

The regulatory landscape for driverless vehicles in the United States is a complex and evolving patchwork, primarily characterized by a division of responsibility between federal and state authorities, with municipalities also playing a role, particularly in operational specifics.

At the **national level**, the National Highway Traffic Safety Administration (NHTSA) and the Department of Transportation (DOT) are the primary federal entities involved. However, the federal government has issued voluntary guidelines and frameworks, such as "A Vision for Safety" and the "Automated Vehicle Framework," which aim to provide best practices and encourage industry innovation while prioritizing safety. These guidelines recommend that states establish their own regulatory frameworks. Recently, NHTSA has relaxed some rules and expanded its Automated Vehicle Exemption Program to include domestically built AVs, making it easier for companies to deploy autonomous vehicles for testing and certain commercial uses (like robotaxis). Legislative efforts, such as the proposed Autonomous Vehicle Acceleration Act of 2025, aim to modernize Federal Motor Vehicle Safety Standards (FMVSS) and create a more cohesive national framework, but these are still in progress. NHTSA monitors the safety of AV testing through its Standing General Order, which requires companies to submit crash reports and incident information. Federal law does not explicitly define liability for AV accidents. This remains largely a matter for state tort law and evolving case law. There are also no federal mandates for AV insurance.

States have taken the lead in developing their own regulatory frameworks for autonomous vehicles, leading to a patchwork of laws across the country. Many states have been faced with the need to enact legislation or issued executive orders related to AVs when those started to be tested in their jurisdictions in the early/mid 2010s, subsequently covering various aspects from testing to commercial deployment. Common themes include allowing operation on public roads, permitting / testing, and addressing commercial use.

California has a robust and relatively strict regulatory framework for AVs. The California Department of Motor Vehicles (DMV) oversees permitting for every stage from testing with a safety driver all the way to driverless deployment. Companies must apply for and receive permits from the DMV. California was one of the first states to enact legislation allowing self-driving vehicles on public roads. For testing with a safety driver, developers are authorized to drive on any public road within the state. For driverless testing and deployment, stricter requirements apply, including specific operational design domains (ODDs) and reporting obligations. Similarly, and in parallel, a robotaxi operator must seek permits from the California Public Utility Commission (CPUC) that also regulates taxi and ride-hailing services. The CPUC regulates passenger service in AVs and its permitting framework considers whether a safety driver is present (drivered versus driverless) and whether a fee is charged (pilot versus deployment). Commercial robotaxi operations require the highest levels of both permits: for driverless deployment (from DMV) and for charging a fee for transportation (from CPUC). California law, like most states, relies on traditional tort principles (negligence, product liability) to determine responsibility and potentially faulty behavior. The question of who is considered the “driver” (human operator, software, or developer...) is existential and still developing through case law. California regulations do not explicitly define liability rules, but they impact how liability might be assigned (e.g., through detailed reporting of incidents). AVs are required to be covered by substantial insurance policies. For instance, for driverless operation, a minimum of \$5 million in liability coverage is typically required.

Texas has a more permissive regulatory environment, generally allowing the operation of AVs on public roads without requiring specific permits or pre-approvals from a state agency for testing or deployment. Texas law states that an automated driving system is considered the “operator” of an AV when engaged, shifting the traditional legal definition of a driver. Companies can generally test AVs on public roads in Texas without specific state permits, as long as the vehicle complies with traffic laws and is equipped with a recording device. There is no state-mandated testing program like in California. Texas law requires AVs to meet standard vehicle registration, titling, and insurance requirements, but does not specify higher insurance minimums exclusively for AVs beyond what applies to conventionally driven vehicles.

Arizona has been very proactive in fostering AV development and deployment, largely through executive orders (dating back as far as 2015) that have created a highly permissive environment. It explicitly allows for both testing and commercial operation of AVs without a human safety driver present, provided the system is monitored remotely. Arizona has no special permits or licenses required beyond standard vehicle registration. Arizona removed the requirement for safety driver in autonomous vehicles back in 2018, making it a favored location for companies to conduct driverless testing and pilot programs. Companies must still comply with all federal and state safety standards; a law enforcement interaction plan is required. Arizona's regulatory framework, by allowing driverless operation, implicitly places more responsibility on the AV system and its developer. AVs are required to meet standard vehicle registration and insurance requirements, similar to Texas, without specific higher AV insurance minimums.

U.S. municipalities typically do not have the authority to create laws that conflict with state or federal regulations regarding vehicle operation. However, they play a crucial role in managing the deployment and impact of AVs within their jurisdictions. Municipalities generally cannot ban AVs that are permitted by state law. However, they can influence AV operations through local ordinances related to traffic management, parking, or specific operational zones. For example, a city might want to establish geo-fenced areas where AVs can operate or regulate pick-up/drop-off points for robotaxi services. In California, for instance, the general area for robotaxi operation needs to be approved by the DMV and CPUC in response to a company's application, and in that, those agencies may react to a city's input in public hearings, but the cities themselves cannot define those areas.

3.4.2. China

The regulatory situation for driverless vehicles in China is very different from the state power monopoly in the U.S., characterized by a combined top-down and bottom-up approach. The national government in Beijing sets strategic directions and key ministries provide high-level guidelines, while local governments (municipalities and to a lesser extent, provinces) are empowered to enact specific regulations, oversee pilot programs, and issue permits for testing and commercial operations.

At the **national level**, several ministries and agencies are involved in shaping the regulatory landscape for ICVs, which include driverless vehicles. Key players include the Ministry of Industry and Information Technology (MIIT), the Ministry of Public Security (MPS), and the Ministry of Transport (MOT). While there is no single, overarching national law specifically dedicated to driverless vehicles, China has a multi-pronged approach. The national government issues guiding principles, policy documents, and draft regulations. For instance, the MIIT, MPS, and MOT have jointly issued guidelines for road testing and demonstration applications of ICVs. These guidelines outline the general requirements for vehicles, companies, and testing scenarios. They are designed to facilitate testing in different regions and speed up technology development.

China has established a significant number of national-level intelligent connected vehicle testing zones (17 by the end of 2024), with extensive open test roads. While still being open to normal traffic, these infrastructure equipped zones are crucial for developing and validating AV technology. Operators that aim to carry out tests with L4 vehicles on selected public roads in pilot cities are required to meet certain conditions set in national guidelines. By August 2024, Chinese public security authorities had issued 16,000 test licenses for autonomous vehicles from nine developers, and nationwide 32,000 kilometers of roads had been opened for testing^{11, 12}. National laws for liability in AV accidents are still evolving. The general principle relies on existing tort law, but the specific allocation of responsibility for accidents involving AVs, particularly those without a human driver, is being addressed through local regulations and is a key area of development. There are no specific national mandates for AV insurance beyond general vehicle insurance requirements. However, national guidelines encourage insurers to develop products that cover the full chain of autonomous vehicle design, manufacturing, personal, and commercial use, as well as data and algorithm services, recognizing the changing risk landscape.

Provinces often build upon national guidelines to create more specific regulations, but the bulk of detailed AV regulations and pilot programs are often implemented at the municipal level, particularly in economically advanced and technologically focused cities. Provincial governments may issue their own guiding opinions or regulations to promote the development of the ICV industry within their jurisdiction. For example, Guangdong province has been proactive in investing in digital infrastructure to support AVs. However, direct permitting for AV operation is typically delegated to the municipal level, especially for large-scale urban deployments.

Municipalities, especially major cities, are at the forefront of AV regulation and deployment in China. Such locations often have designated special “Intelligent Connected Vehicle Demonstration Zones” in which the local government has the authority to issue regulations, to open roads for testing, and even may permit commercial operations. One example of such a zone is the Beijing High-level Autonomous Driving Demonstration Area described below.

¹¹ https://english.www.gov.cn/news/202408/27/content_WS66cd745ac6d0868f4e8ea485.html

¹² <https://www.spglobal.com/mobility/en/research-analysis/china-autonomous-vehicles-development.html>



Figure 5: Baidu Apollo Go robotaxi in the Beijing High-level Autonomous Driving Demonstration Area [Sven Beiker]

Beijing has been a national leader in autonomous vehicle development, establishing the world's first high-level autonomous driving demonstration zone in September 2020. Beijing passed new regulations on autonomous vehicles, effective April 1, 2025, which explicitly encourage and support technological innovation.¹³ These regulations provide a clear framework for Level 3 and higher AVs, including infrastructure planning for the government and safety assurance. The 600 square kilometer Beijing High-level Autonomous Driving Demonstration Area¹⁴ in the southern part of the city has issued road test permits to numerous companies, most notably Baidu, Pony.ai and WeRide, allowing testing with and without safety drivers. Companies must meet rigorous testing requirements, including annual inspections for operational AVs.

Shanghai is actively expanding its autonomous driving test roads and accelerating development of its smart mobility ecosystem. It has implemented its own regulations and guidelines for testing and demonstration. The city has expanded its autonomous driving test roads to over 750 kilometers. Like Beijing, it focuses on integrating smart infrastructure to support AV deployment and robust testing.

Guangzhou is a significant hub for AV development and has issued local regulations and permits for AV testing and pilot commercial operations, particularly for robotaxis and autonomous logistics. The city has designated a number of significant areas for AV testing and operation, often focusing on specific use cases like robotaxis, AV shuttles, public transit and logistics.

Shenzhen was the first city in China to permit autonomous vehicles on public roads following the implementation of its regulations on intelligent connected vehicles in August 2022. These regulations are considered leading for their clarity on legal status and liability. They allow L4 automated vehicles to operate unmanned on designated roads. Vehicles are required to allow for remote human override in unsafe scenarios and have an exterior signal light for autonomous driving. Shenzhen's regulations are notable for explicitly clarifying liability rules: the driver is liable for accidents in AVs with a driver, while the owner/manager is responsible for those without a driver. Shenzhen's regulations encourage insurers to cover the full chain of autonomous vehicle design, manufacturing, and use, recognizing the need for adapted insurance products.

¹³ <https://www.chinadaily.com.cn/a/202412/31/WS67739cdaa310f1265a1d851f.html>

¹⁴ <https://epaper.chinadaily.com.cn/a/202404/19/WS6621a171a310df4030f50f3c.html>

Wuhan has been actively involved in AV development, particularly through its national intelligent connected vehicle demonstration zone. It has issued permits for testing and pilot operations, including robotaxis. The city has established dedicated test zones and routes for autonomous vehicles. The focus is on creating a comprehensive environment for various AV scenarios. Wuhan's regulations on liability and insurance align with the national and municipal trends of developing clearer frameworks as the technology matures.

3.5. User studies

A JD Power user study on robotaxis¹⁵ published in October 2024 gathered responses from 3,773 persons, of which slightly over 20% were living in cities with self-driving vehicle services (Dallas, Las Vegas, Los Angeles, Phoenix, and San Francisco), and of those not all had actually used the service. Overall, those who identified as robotaxi passengers rated the driverless riding experience to be an 8.53 out of 10, with the leading factor in that experience being “vehicle technology.” JD Power found that “consumer confidence” when riding in a robotaxi was 76% among those who have ridden in one, compared to 20% among those who have not. It was also noted that non-riders in cities with robotaxis also saw higher consumer confidence (34%) compared to non-riders in all cities, served by robotaxis or not. When asked to describe their ideal robotaxi service, respondents consistently gave image attributes like safe, reliable and trusted. It was furthermore found that until robotaxi providers can fulfill needs pertaining to the specific locality in terms of availability and cost, such services will remain simply a novelty and not a significant transportation solution.

A South Korean study from 2022¹⁶ surveyed users of a robotaxi service, at that time implemented in Seoul and Daejeon, and could identify that the ride experience was the strongest driver of user acceptance. Emotional responses—particularly excitement and apprehension—also played significant roles.

Zhang et al. (2024)¹⁷ surveyed 480 actual users (August–September 2024) of Baidu Apollo Go’s robotaxis in Wuhan. The survey aimed to explore the primary factors affecting consumers’ willingness to use autonomous taxis and used several statements that the respondents were asked to assess on a 7-degree Likert scale (from “strongly disagree” to “strongly agree”). Statements included e.g. perceived usefulness, where the following items were to be rated:

- Using autonomous taxis improves my travel efficiency.
- Using autonomous taxis allows me to complete my travel plans more quickly.
- Using autonomous taxis makes my travel experience more relaxing.
- I believe that autonomous taxis are very useful for my travel needs.

Among the findings it was noted that perceived usefulness is significantly positively influenced by attitude (e.g. “I believe that autonomous taxi technology is valuable”), subjective norms (e.g. “The important people around me think I should use autonomous taxis”), and perceived cost–benefit (e.g. “Using autonomous taxis can help me save both money and time”). The perceived usefulness and perceived ease of use influence the “intention to use”, while “perceived risk” (e.g. “I am concerned about the safety of autonomous taxis” and “Using autonomous taxis may lead to the leakage of my

¹⁵ <https://www.jdpower.com/sites/default/files/file/2024-10/2024117%20U.S.%20Robotaxi.pdf>

¹⁶ Lee, S., Yoo, S., Kim, S., Kim, E., & Kang, N. (2021). Effect of Robo-Taxi User Experience on User Acceptance: Field Test Data Analysis. *Transportation Research Record*, 2676(2), 350-366. <https://journals.sagepub.com/doi/10.1177/03611981211041595> (Original work published 2022)

¹⁷ Zhang et al. (2024) – *Factors Influencing Use of “Apollo Go” in Wuhan*, *Behav. Sci.* 2024, 14, 1216. <https://doi.org/10.3390/bs14121216> <https://www.mdpi.com/journal/behavsci> *Behav. Sci.* 2024, 14, 1216 2 of 18

personal information”) significantly reduces the positive effect of perceived ease of use and perceived usefulness on the intention to use (e.g. “I am open to trying autonomous taxis in the future”; and “I plan to use autonomous taxis for my travels in the future”). It is furthermore concluded that marketing and user experience initiatives play a critical role. Public testing events and social media campaigns can give consumers a more direct experience of the convenience and safety of autonomous taxis, fostering a positive attitude toward their adoption.

4. Experiences from deployments (U.S. and China)

The following sections are largely based on the stakeholder interviews and focus groups conducted as the core part of this study. They provide insights in the deployments of robotaxis in cities and the experiences that different stakeholders – from regulators to users – have made. Observations and findings are further analyzed in section 6 with respect to learnings for robotaxi deployment in Sweden/Europe.

4.1. Municipalities

Municipal administrators consistently stated that California cities possess limited authority over robotaxi deployment. Interviewees indicated that state regulation does not consider the interests of local municipalities enough, significantly restricting their ability to influence deployment decisions. For example, interview participants noted that companies like Waymo and Cruise have just merely informed municipalities of their plans, often directing them to websites for additional information. This approach, according to municipal officials, has led cities to feel that these companies are primarily focused on identifying business opportunities within large metropolitan areas characterized by favorable travel patterns.

To ensure the beneficial integration of advanced transportation technologies, municipalities emphasized the critical need to proactively define their expectations for robotaxi implementation. As one interview participant aptly stated, as an advice to cities: *“don't wait for a request, define what you are looking for”* before introducing such advanced transportation. Without clearly articulated needs, robotaxi deployment risks becoming a source of disruption rather than a beneficial addition, let alone a much-needed solution.

Also, interview partners stressed that cities must demand performance data and implement metrics to track deployment progress. When engaging with these technologies, cities asserted that they should ask critical questions regarding how robotaxis will improve local mobility and the overall transportation system, and how the technology can genuinely benefit various segments of the population, and not just young, affluent, tech-savvy city dwellers. By establishing regulatory frameworks in advance, cities can prevent issues, ensuring that robotaxi integration is controlled, addresses genuine urban needs, and avoid merely introducing vehicles into existing infrastructure which can cause unforeseen problems.

Municipalities are clear in that for robotaxis to be truly beneficial, they must actively contribute to solving existing urban issues such as parking problems, traffic congestion, inequality, or safety

What is so special about the curbside in robotaxi deployments?

Effective curbside management is crucial for robotaxi deployment and regulation. It's one of the few areas where U.S. cities, particularly in places like California, have significant authority over their streets. The curb is the intersection where local interests, like parking and loading zones, meet the flow of traffic.

For robotaxis, the curb serves as a vital zone for passenger pick-up and drop-off and for temporary staging. Cities can manage these areas by assigning specific zones, charging fees, and using real-time communication and sensors to optimize space and traffic flow. This prevents robotaxis from impeding traffic and ensures passenger safety during entry and exit. Since cities have limited control over what happens on the road itself, actively managing the curbside is a necessary way they can regulate and integrate these new services smoothly, thereby increasing public acceptance.

concerns, and to moving more people efficiently within existing street networks. The overall transportation system needs to work, meaning less traffic overall and fewer parking problems.

Local authorities and urban planners expressed significant concerns regarding the lack of substantive data on the impacts of robotaxis, both positive and negative. They pointed out that companies like Waymo have been accused of inefficiently using street space and contributing to traffic, noting that for instance Waymo vehicles in San Francisco often travel empty. This highlights the tension between the private sector's pursuit of profit and communities' need for livable spaces. Municipalities voiced worry about the potential for private sector goals to conflict with community interests in maintaining a high quality of life.

Therefore, municipalities are pressing for specific use cases where robotaxis demonstrably make sense, rather than passively allowing companies to introduce vehicles into their cities. To improve the integration of robotaxis, municipalities repeatedly

emphasized the imperative to get performance data from robotaxi operators, establishing a more cooperative approach for the two parties. Future deployments, according to city officials, should prioritize building trust - among citizens, users and also municipality officials - demonstrating transparency, thoroughly documenting safety, clearly defining their operational design domain, and strategically choosing locations (especially pick-up and drop-off points) to avoid disrupting traffic flow.

California's approach to robotaxi deployment is generally regarded as effective from a safety standpoint, as these vehicles exhibit a commendable safety record in comparison to conventional ride-hailing services. Nevertheless, cities within the state have expressed substantial concerns, primarily concerning operational aspects. For instance, San Francisco has encountered challenges due to inadequate participation in the deployment process, resulting in preventable issues such as robotaxis obstructing streets and hindering the access of emergency vehicles. This critical requirement for aligning robotaxi deployment with city requirements emphasizes the significance of proactive regulation, which assists cities in avoiding a "scooter-geddon" scenario – the chaotic influx of electric scooters that frequently arrived without adequate planning, leading to widespread clutter and safety hazards.

This suggests that while robust safety regulations are essential, enhanced municipal involvement is paramount for a smoother integration. Otherwise, problems are compounded when robotaxi companies often interact primarily with state-level entities like the California DMV and CPUC, rather than directly with the cities. Arizona – by comparison – provides a strong example of effective collaboration, with closer relationships between cities (e.g., Chandler, Mesa, Phoenix) and robotaxi companies. This tighter alignment has generally resulted in a more effective and less problematic deployment. Both California and Arizona's experiences strongly emphasize that city involvement is not just beneficial, but often imperative for successful robotaxi integration.

Furthermore, observations from China reinforce this point, where high levels of city involvement are considered crucial, if not absolutely necessary, for the successful rollout of robotaxis. As pointed out earlier, the local administrations have a strong say regarding transportation solutions, including robotaxis. Therefore, it is known that they closely monitor the deployment of those services on their streets and take action as necessary. That may mean limiting operation areas and hours, suspending services during extreme weather (e.g. typhoon), or requesting data. However, this could not be researched in more detail and interviews with local representatives could not be conducted as part of this study, which might be something to pursue in a follow-up project, if of interest.

All this shows that a significant challenge in robotaxi deployment lies in bridging the gap between the often-divergent goals of corporations (revenue generation, technological leadership etc.) and those of cities (providing better transport options, alleviating traffic congestion and enhancing street safety etc.).

4.2. Regulators

Regulators in California expressed that their motivation to support the implementation of robotaxis is the promise that the technology may significantly enhance traffic safety. The technology's potential to mitigate issues like distraction, fatigue, and incapacity in drivers is seen as a benefit that, if true, becomes almost imperative to seize. Beyond safety, regulators also highlighted the promise of unlocking mobility for yet underserved community members and aiding in logistics and goods movement. Demand for regulation has largely originated from technology companies and research organizations, with leading players actively seeking regulatory certainty for their testing and eventual deployment. Since no federal regulation existed in the early phases, the states like Nevada, California, Arizona and others stepped up to develop their own frameworks, which were described in earlier sections of this report.

Regulators emphasize the importance of connecting equally with both the industry and various advocates, including those focused on safety and consumer rights. In that sense, the core task of the California Department of Motor Vehicles (DMV) is to protect the public, necessitating a thorough review of incidents and ongoing engagement with companies to learn about their plans and progress. AV developers in California are generally considered “good actors” and aware of the risks involved. Regulators in California also stress the support of external experts, particularly from academia, such as UC Berkeley PATH, who assist in reviewing documents companies submit as part of the application process and in reviewing cases when things go wrong and action needs to be taken.

The regulatory process of the DMV involves a series of questions to vet a company’s readiness. Evidence must be presented how the automated driving system (ADS) handles various factors specific to its Operational Design Domain (ODD). Regulators also scrutinize how the ADS behaves at the edge of its ODD, such as pulling over, stopping, or calling a remote operator. This is typically not a rigid checklist but rather a tailored review of each developer’s safety case, with incident investigations often referring back to the initial responses. Remote monitoring is a mandatory requirement, though the specific methods of interaction with the ADS are not prescribed.

It is noted that immobilizations were underestimated, that means situations where the robotaxi cannot complete its driving task and reaches a minimum risk condition, i.e. just stops in location and may block active traffic. Regulators now recognize the need for specific reporting requirements around such events and are actively engaging with companies to find solutions. Furthermore, regulators stress the importance of getting leading indicators like unexplained hard braking, immobilizations, and braking profiles, in addition to lagging indicators such as crashes, to proactively understand challenges. In that context it is interesting to know that traffic citations have been implemented for AVs in California, which then trigger special investigations by the DMV.

Overall, regulators see themselves confronted with free market forces pushing robotaxi deployment, with many companies based around San Francisco eager to test their products and eventually cash out big business. While regulators seem aware of risks that a proliferation of robotaxis may present, a region's openness to adopting new technologies needs to be balanced and, in several cases, has facilitated their emergence. For those reasons, in California for instance, the CPUC puts forth at the beginning of the implementation process a checklist, especially focused on a Passenger Safety Plan. Applications are reviewed and discussed with applicants to ensure compliance with rule and to stay abreast of industry advancements. Public hearings, which involve full commission voting, are required for the approval of deployment permits for companies, providing a channel for public comment. It is interesting to know how the two agencies in California have two different but complementary perspectives: the CPUC's core interest is passenger safety while the safety of all road users is a primary objective of the DMV.

Regulators have observed negative public reactions toward robotaxis, not seldom nested in an inherent tension surrounding new technologies, which autonomous vehicles have brought to light. While many people are keen to embrace new technology, with some even visiting San Francisco specifically to experience AVs, there are

also concerns about the broader implications of AI and the influence of tech firms. The visual juxtaposition of affluent young people in robotaxis and homeless individuals on the streets was noted as further source of social divide, indicating a two-minded public sentiment within the City by the Bay.

In relation to privacy, regulators may have broad authority to collect operational data such as number, time, and location of trips, they do not specifically collect data related to users and citizens. Data collection is not about mobility behavior on an individual level but rather about safety, sustainability, and efficacy of vehicles on a fleet level. Companies are permitted to redact some data to protect their business interests.

Why San Francisco sued the CPUC over robotaxis

In August 2023, the California Public Utilities Commission (CPUC) granted Waymo and Cruise permits to expand their fleets and paid-passenger services through all of San Francisco. This decision was met with "months of frustration" from San Francisco leaders, who have no authority over the autonomous vehicle industry, as it is controlled by the state. City officials highlighted numerous incidents of autonomous vehicles disrupting traffic and emergency services and unsuccessfully requested a rehearing from the CPUC.

In November 2023, the CPUC rejected San Francisco's request for a rehearing, stating that the city had not proven any legal error in the commission's decision. In December 2023, San Francisco filed a lawsuit against the CPUC, seeking to overturn its August decision and force Waymo to roll back its expansion. San Francisco City Attorney David Chiu argued that the CPUC failed to consider the risks to public safety and environmental impacts.

The city's legal challenge was ultimately rejected by a state court in January 2025. The court's three-judge panel unanimously denied the request to overturn the CPUC's decision, noting that the city failed to prove that the Waymo permit was granted without meeting legal requirements. The court concluded that the incidents cited by San Francisco were "relatively minor" and that the CPUC had considered the city's safety concerns.

Following San Francisco's lead, San Mateo County has also expressed concerns over Waymo's plans to expand into its jurisdiction and is seeking more control over the regulation of autonomous vehicle operations.

4.3. Citizens, users

In the focus groups that were conducted as part of this study, participants provided their perspectives

Residents taking action – some hiccups along the route

Waymo's rollout of robotaxis across Arizona, California, and Texas has faced persistent public pushback, often escalating into direct acts of resistance. In Arizona, where Waymo began testing in Chandler in 2016, residents expressed anger at the sudden arrival of autonomous vehicles without community input. Over the years, people slashed tires, threw rocks, attempted to run vans off the road, and in one case pointed a gun at a vehicle. Police recorded at least 21 such incidents, with many residents citing fears about safety and job loss after the fatal Uber self-driving crash in nearby Tempe.

In California, particularly San Francisco, discontent has manifested in creative and disruptive protests. A group of activists known as Safe Street Rebel popularized the "Week of Cone," in which they disabled Waymo and Cruise robotaxis by placing traffic cones on their hoods. The campaign symbolized frustration with vehicles blocking traffic, interfering with buses and emergency services, and operating without meaningful community consent. Tensions escalated further in 2024 when a crowd in Chinatown vandalized and set fire to a Waymo vehicle using fireworks. Residents also raised quality-of-life concerns, complaining of incessant honking from Waymos in a company-owned parking lot neighboring a residential area.

In Texas, Waymo's expansion into Austin has been met with skepticism and resentment from some locals. Activists and residents voiced concerns over traffic disruptions, safety risks, and the lack of public engagement before deployment. Critics argued that autonomous fleets were imposed without consent, echoing frustrations seen in Arizona and California. This resistance highlights that Waymo's technological challenges are matched by social ones: skepticism, anger, and sometimes outright hostility from the very communities the company aims to serve.

However, after initially wanting to remove robotaxis, San Francisco residents and tourists have grown to embrace them. Waymo's self-driving cars have become a common sight, with tourists at the Golden Gate Bridge Welcome Center recording videos of the vehicles that brought them there. Near the city's Ferry Building, multiple driverless cars drop off and pick up both locals and visitors. An article published in the Wall Street Journal suggests that tourists and locals "can't get enough" of the robotaxis.

regarding robotaxis often as a comparison to other transportation options, primarily ride-hailing services like Uber and Lyft, but also public transportation systems and personal car ownership. Those comparisons highlight the perceived advantages and disadvantages of robotaxis in the context of familiar alternatives and also the competitive situation that arises among an increasing number of transportation solutions.

Several positive aspects of robotaxis were expressed, with safety being a prominent factor. Many users report feeling safer in robotaxis than with human drivers or on public transit, as they don't need to fear another rider's or a driver's harassment or even assault. Interestingly enough, this does not seem to be a concern in China where the crime level is allegedly much lower. That highlights that respective advantages of robotaxis in the United States may not play out in other regions in the same way. In both regions users cite the smooth and predictable driving style of autonomous vehicles. The convenience and ease of use are also appreciated, including 24/7 availability (however limited in some Chinese locations due to

low user demand and therefore less interest by the providing companies), consistent service quality that a professional operator like a robotaxi company can guarantee (as opposed to occasionally dirty vehicles or unpleasant driving with a human registered as a driver in the gig-economy), and appreciation of privacy through the lack of a human driver. Furthermore, some users find the cost of robotaxis competitive, especially when considering the absence of tipping. However, the pricing was subject of diverging views in the focus groups: while some users say "Waymo is much cheaper than ride-hailing...", others say "It costs about the same, if not more...". This may be a hint that users often do not really know how much they pay for transportation if it is not just the daily bus ride to or from

work (more about this also later in this section). Robotaxis are also recognized for their potential to improve accessibility for individuals who cannot drive, such as the elderly or visually impaired.

However, focus groups also revealed several areas for improvement. Limitations such as restrictions in the areas (in China also the limitation of operating hours) served and the routes where robotaxis are allowed to travel, (e.g. not on highways) are of concern, as well as issues related to drop-off at a point other than the one requested, at a point that feels unsafe, in the middle of a puddle etc. It was noted during test rides in China that companies are recognizing and addressing such deficiencies, for instance in Pony's robotaxis, the user can move the drop-off location by about 50 meters, if desired. There is also the perception that robotaxis can be slower than traditional ride-hailing services when the robotaxi chooses less complex but therefore potentially slower routes and also because it respects speed limits. As noted in the previous paragraph, some find robotaxis cost-competitive, others consider them more expensive than alternatives. (The project team found the pricing of Weymo in San Francisco similar if not higher compared to Uber / Lyft, and one needs to consider that for services with human drivers still a 10-20% tip needs to be added, but not for driverless services. In China, pricing of robotaxi services seem to be like human-driven vehicles such as those brokered by the ride-hailing leader DiDi). The use of "dynamic pricing", when the price is set based on demand and supply, is disliked in a similar fashion as for ride-hailing services because customers feel tricked and their travels become less predictable. User interaction and the app interface are other points of criticism, such as that the app may not be intuitive enough, which should not be underestimated as it may sway users from one transportation solution to another. In China the project team experienced even more the challenges that international travelers are faced with if they first need to set up a user account and may not understand the language or not even script signs. The focus group participants expressed concerns regarding assistance for riders with specific needs, such as help with in- and egress that a human driver can provide but not a robotaxi. Broader social concerns are also raised, including the potential for job displacement and the lack of social interaction.

To realize the full potential of robotaxis, users suggest several key improvements. These include first and foremost more precise pick-up and drop-off procedures but also enhancing accessibility for visually impaired riders. Better integration with public transit systems (e.g. first / last mile service, unified payments etc.), increased transparency on safety were also recommended. Finally, the practical incorporation of features like luggage space, bike racks, and child seats were pointed out, all things that may seem not specific to robotaxis but are typically lacking in the vehicles that still have some appearance of test vehicles and there is no human who can be asked for instance whether a suitcase can be placed in the trunk (although all vehicles include a user service feature through which inquiries could be addressed).

At the end of the focus groups sessions, the participants were asked for their individual single-word suggestion about what Sweden should consider when implementing robotaxis. Those suggestions were compiled into a list and presented to Chat GPT with the prompt: "Write a statement outlining what Sweden should consider when deploying robotaxis in the near future. This statement should emphasize the following key aspects..." The statements generated by the focus group participants, which the respective participants generally agreed with, are intended as snapshots to give a flavor of those sessions:

"As Sweden deploys robotaxis, it must ensure seamless curbside management, top-tier safety, and a human-centered approach that preserves choice and inclusiveness. Geofencing should optimize efficiency, while integration with public transport prevents cannibalization and enhances mobility overall. Affordability is key to making robotaxis accessible, ensuring cost is not a barrier. Ultimately, the goal is societal benefit—improving mobility, reducing emissions, and enhancing urban life. By prioritizing these factors, Sweden can create a sustainable, equitable, and efficient autonomous transport

system that complements existing infrastructure while addressing diverse mobility needs.”

Focus Group, San Francisco – February 27, 2025

“Sweden’s deployment of robotaxis must prioritize safety, ease of use, and accessibility while ensuring public trust. Advanced systems must handle urban complexity and harsh winter conditions like snow and low visibility. A seamless, inclusive user experience is key, fostering emotional acceptance through comfort and transparency in decision-making. Strong regulations should define safety, liability, and ethical AI use. Intelligent adaptation to real-world challenges and a sustainable business model will ensure viability, balancing affordability with service area expansion. By integrating these elements, Sweden can lead in safe, intelligent, and inclusive autonomous mobility.”

Focus Group, Palo Alto – February 28, 2025

4.4. AV developers

In a series of interviews with developers concerning Californian, Chinese and more general perspectives on robotaxi operations, several common motivations and challenges emerged, alongside distinct regional nuances.

A key similarity across all perspectives is the understanding that fleet size matters significantly for financial viability. Interviewees pointed out that at least a couple of hundred vehicles is typically required for operations to be financially sustainable, making small pilot programs less interesting from a business point of view. This translates to a general consensus that deployments are less likely in smaller cities (below a population of 500,000 was cited in some interviews) or even rural areas. When selecting a city for deployment, interview partners universally stressed the importance of carefully assessing population size, the quality of existing public transportation (it should encourage people not to use personal cars but not be so excellent that robotaxis are dismissed), a comparatively high share of high-income population, and access to airports to maximize business.

Differences in market aggressiveness and user expectations were highlighted between regions. Interview partners noted that the cost equation is much more aggressive in China than in the U.S., potentially also with several companies operating in parallel presenting an even more competitive situation. Furthermore, customer wait time is a key performance indicator, with interviewees explaining that waits exceeding three minutes are often considered too long, especially in China where the expectation on prompt service is even more pronounced than in the U.S.

Regulatory environments and their impact on deployment presented both similarities and differences. Overall, it was stated that regulation can significantly slow down deployment due to lengthy certification and testing processes. California was deemed acceptable in this regard, while Europe was characterized as too lengthy or having non-existent frameworks in crucial areas. The Chinese perspective agreed with this, explaining that regulation operates on a city-by-city basis, with agencies' responsibilities also varying per city, though this might change after pilot phases. Despite these challenges, Chinese cities generally seem to view robotaxis as a beneficial addition to their transportation services and as catalysts for good partnerships.

Regarding deployment challenges and lessons learned, the Californian experience offered specific insights. Interviewees explained that they learned a lot through implementation, such as enabling police to enter and drive off a stuck robotaxi. Partnering with airports proved difficult due to their semi-private nature and the inability to communicate directly with an autonomous vehicle if it gets stuck, with Phoenix being easier than San Francisco due to a seemingly more business-friendly culture when it comes to robotaxis and an airport with fewer ground transportation problems than San Francisco International.

Underestimated aspects typically present very specific, if not irrational situations, such as for instance a robotaxi in San Francisco pulling over right in front of a house on fire due to misinterpretation of the fire trucks. In general, companies also see significant challenges when moving from one city to another, such as traffic patterns are very different in Phoenix and San Francisco or in Beijing and Shenzhen. Such examples also include Austin's horizontal traffic lights and police officers directing traffic on horseback, and the vast differences in training machine learning models for environments like Japan. San Francisco's complex layout and rush hour traffic contrasted sharply with simpler grids like Chandler,

Arizona. While New York City was seen as a large ride-hailing market, its difficult traffic would probably make the business case unviable (however, Waymo is mapping The Big Apple already¹⁸).

When asked about public transport integration, observers state that the initial focus in California was more on ride-hailing due to a presumed better business case. A Chinese interviewee stated that: *"integration of robotaxis with public transport does not currently make sense"* because robotaxis offer a premium service with better user experience, cleanliness, security, convenience, comfort, and privacy, going far beyond a mere shuttle. They also stated that increased congestion and cannibalization of public transport are not concerns, as robotaxi pricing will not undercut transit. While quantitative data on effectiveness and impact is still limited, qualitative feedback highlights safety, security, privacy, and convenience.

Chinese companies are experiencing franchise requests, including from municipalities, with motivations ranging from filling gaps in the transportation landscape (e.g. shuttles in office parks) to experimenting with new mobility solutions (also giving certain organizations / locations a more advanced and innovative image). However, it needs to be kept in mind that robotaxis are not yet a

What is so special about robotaxis at airports?

Airports are crucial for robotaxi deployment due to a combination of high customer demand, assumed profitability, but also significant operational challenges. A strong business case is predicted because airports generate a lot of ground transport demand with a high willingness to pay by users. Such trips are often longer than in downtown areas only, which is also good for ride-hailing / robotaxi business.

However, deploying robotaxis at airports is highly complex and regulated. Unlike city streets, airports have their own authorities with strict rules and permitting processes. Operators must prove that their vehicles can navigate these intricate environments safely and predictably, interacting with emergency vehicles, public transport, and other road users without causing disruption or congestion. That is even more important as departure and arrival areas are notoriously congested and erratic.

With airports being one of few significant taxi businesses that are left, their drivers raise concerns about job displacement and safety. For now, discussions and pilot projects, such as Waymo's mapping at San Francisco International or Pony's Shenzhen Baoan and Beijing Daxing services, are a step forward, but full commercial passenger operations remain a significant hurdle. Ultimately, while robotaxi companies need airports for their business model, many airports don't see a pressing need such that one interview partner expressed: *"they need us, we don't need them"*.

¹⁸ <https://techcrunch.com/2025/06/18/waymo-has-set-its-robotaxi-sights-on-nyc/>

consumer product, and human operators are required on-site for handling vehicles in the depot, servicing and supervision. This also shows that, while the ultimate business model for the robotaxi companies is yet to be found, there can be many components that the companies can consider to further monetize on their offer, ranging from licensing software to selling and operating entire fleets. To put this into context, it is important to note that for instance it took Uber 15 years to reach profitability¹⁹, which was ultimately achieved through much innovation in business and service components as well as experimenting with markets and partners.

Overall, it was noted that while the global robotaxi movement is driven by a common need to address driver shortages and improve financial viability through cost reduction, regional approaches differ. California has focused on learning through practical, often complex, urban deployments and addressing specific operational challenges like interacting with emergency services and adapting to diverse cityscapes. There are concerns about highway driving, where a stuck car could trap passengers, and the high economic and business liabilities associated with highway trucks. China is pushing aggressive expansion with a strong focus on premium user experience and clear scaling targets, while Europe is seen as needing to better understand how to properly utilize this emerging technology for societal benefits and amidst more challenging regulatory landscapes. Finally, a succinct yet powerful statement was made: *"Europe needs to understand how to use this technology properly."*

4.5. Operation partners

Robotaxi operation services emphasize that their role complements that of developers or municipalities. Developers design, test, and provide the vehicles for deployment, while municipalities adopt them into their existing transportation ecosystem. A key realization in California was that AV developers/vehicle providers do not want to be in the business of managing or owning large fleets. Operation plays a crucial role in the middle, including running the vehicles, servicing them, providing oversight, and ensuring safe, efficient, and effective transport. While developers or municipalities may also assume the role of operators, there is a distinction in robotaxi services.

Interviewees indicated that AV developers communicated road safety as a primary benefit of robotaxis, but generating business was likely an equally significant motivator. In California and other U.S. locations, the integration with public transport was not mentioned to be a major factor. In contrast, the convenience of driverless on-demand mobility for individual passengers was highlighted in contrast to traditional public transport that can simply not be flexible enough for just one or two people due to cost constraints.

A consistent theme in interviews with operation partners was that Europe lags significantly in automation technology. Small-scale deployments, such as "15 vehicles in Oslo or 5 in La Rochelle," do not substantially contribute to technological maturity compared to larger-scale operations in the U.S. and China. Again, one interviewee in China pointed out that they are "not interested in pilots anymore, really need to go to real business". However, it was acknowledged that Europe still can make significant contributions to the value chain through operations, vehicle electrification, and developing safe, redundant electric drive platforms. Interviewees in operations observe that France's AV efforts are driven by Public Transport Organizations (PTOs), while Germany's are driven by Original Equipment Manufacturers (OEMs).

Robotaxi operations experts acknowledged that, while some level of public acceptance challenges were anticipated, there were several aspects that were overlooked in the deployment of robotaxis in California. This was in particular the assurance toward users and members of the public that these vehicles would be sufficiently safe. In this context, it was noted that Europe's attempts to apply metrics from fields such as aviation may not help this cause much, while the United States' and

¹⁹ <https://www.theverge.com/2024/2/8/24065999/uber-earnings-profitable-year-net-income>

China's approach to primarily rely on reporting miles driven seem to be easier to comprehend for laypeople. Additionally, it was pointed out in the interviews that interactions with first responders, such as Waymo's tendency to bring vehicles to a halt when recognizing an emergency vehicle's siren even when that was several blocks away, presented unforeseen challenges.

Furthermore, it was mentioned that the robotaxi business case itself contains numerous unanticipated costs. Despite significant advancements and optimistic market outlooks, profitability remains a challenge: while companies are reducing production costs and aiming for profitability by 2029, the high costs of software, maintenance, and research continue to pose difficulties.

Looking ahead, operation managers emphasized that future deployments should prioritize adequate electric charging for robotaxi fleets as those vehicles often use advanced powertrains and such infrastructure is a prerequisite for widespread implementation.

4.6. Researchers

Academics across various fields are interested in robotaxis for their potential to address significant societal challenges and advance their respective disciplines. Safety advocates are naturally interested in how robotaxis could help achieve "Vision Zero" goals by dramatically reducing traffic collisions and fatalities, a primary societal benefit. This also appeals to economists, who view the fewer accidents from a different angle, recognizing the positive economic impact of reduced damage and insurance payments across the entire economy. For engineers, computer scientists, and robotics experts, robotaxis are a fascinating intellectual and technological pursuit, representing a complex challenge in AI, robotics, and system integration. Urban planners see robotaxis as a solution to enhance urban mobility, particularly by providing efficient first- and last-mile transport. Meanwhile, transportation researchers are focused on how these vehicles can improve cost-effectiveness and service quality for the public. Lastly, automotive management scholars are intrigued by the competitive landscape and business prospects surrounding this new technology. Each of these fields approaches the topic from their unique perspective, collectively contributing to a comprehensive understanding of the multifaceted impact of robotaxis.

Academic interviewees agree that industry, rather than public agencies, is driving the development of robotaxis. Partnerships are considered essential, with companies like Waymo having invested years in building relationships with advocacy groups, regulators, and transportation stakeholders. In the United States, business-to-business approaches, such as working with transit operators to access rider bases, are seen as more effective than direct consumer acquisition.

Public perception remains a significant challenge. Minor incidents have often been amplified by social media and political agendas, while the need for broader education of both the public and policymakers has been underestimated. Technical hurdles, including vehicle wear rates and the complexity of providing true curb-to-door service, were also noted as underestimated issues.

Economics pose another major obstacle. With vehicle costs between \$150,000 and \$200,000 and high operational expenses, researchers view profitability as a distant goal. Heavy subsidies for U.S. transit, around 80 percent compared to less than 30 percent in Europe, make cost comparisons difficult. Some interviewees suggested that investor impatience may push companies toward freight and goods delivery, which are technically simpler and potentially more profitable.

Researchers emphasized that successful deployment requires strong reporting standards, meaningful driverless testing criteria, and effective remote monitoring capabilities. Remote assistance is already standard, but questions remain about how to scale oversight safely.

Looking ahead, future strategies must balance innovation with equity, sustainability, and viable business models. Services should target underserved routes, integrate with public transport, and avoid becoming isolated stand-alone offerings. Current robotaxi ride costs resemble those of ride-hailing,

making them inaccessible for low-income users, and pooling – already limited in conventional ride-hailing – shows little promise. Standardized performance metrics for safety, comfort, and efficiency are essential to compare autonomous systems with human drivers and ensure transparent benchmarks. Europe in particular has an opportunity to take the lead in defining such standards rather than leaving them to industry.

The trajectory of robotaxi deployment will be shaped as much by politics, perception, and economics as by technology. Progress will require patient capital, regulatory clarity, transparent reporting, and above all, a strong focus on the end user. As one interviewee observed, “*even incremental improvements over the current system can deliver meaningful benefits*”, but long-term success depends on demonstrating value not only to investors and innovators but also to cities, riders, and the wider public.

5. Expectations prior to deployments (Sweden)

5.1. Municipalities

Swedish municipalities are looking at the future deployment of robotaxis with a mix of curiosity and hesitation. Their primary considerations are climate goals, urban planning, and maintaining technological competitiveness.

The urban planners and administrators that were interviewed for this study have limited immediate interest in robotaxis, partly due to the small size of the existing taxi market. Instead, some cities are focusing on other automated vehicles, such as delivery robots, having already seen successful deployments for goods delivery and waste collection. They recognize the complexity of integrating these technologies and the need for human supervision.

In contrast, other cities that have historically paid less attention to automated mobility are now giving it more consideration as robotaxis become a more realistic possibility. Their main motivations are climate protection and reducing traffic congestion. They are proactively exploring deployment goals, potential infrastructure needs, and their own role in facilitating these services, all while anticipating future regulatory changes.

Some cities hold a more cautious, “yes, maybe” position. While admitting a lack of understanding about the technology, they are interested in leveraging automated vehicles but worry they could increase the number of vehicles and even generate traffic of empty vehicles. Robotaxis are not yet a firm part of their long-term transportation plans. These cities also see automated solutions as a way to reduce the number of private cars on the road and to provide better first- and last-mile connections for persons living in rural areas. They also hope that self-driving vehicles could help address challenges like driver shortages and high operating costs.

Across the board, municipalities share several key concerns. Many anticipate a stressful process if a robotaxi company were to launch services in their jurisdiction, though they also believe robotaxis could quickly become a normal part of life and even reduce accidents. Cities are keen to learn from existing commercial deployments, with a particular interest in understanding how robotaxis affect mobility behavior and public safety.

A common goal is for robotaxis to act as a feeder system for public transport, providing connections to and from train stations and trunk lines, which aligns with climate neutrality objectives. There is a strong consensus that these vehicles must be electric. The importance of combined mobility, which integrates robotaxis with public transit and shared mobility solutions, is also a top priority for some cities.

Data is highlighted as crucial for understanding how people and goods move. Cities recognize the value of inter-city collaboration and learning from past challenges, such as the initial chaos of e-scooter deployments. A dialogue, particularly involving local politicians, is seen as essential for resolving multiple goals, e.g. regarding climate protection, accessibility, and congestion.

Municipal administrators acknowledge that regulations can hinder deployment due to lengthy certification and testing processes. There is a strong desire for Sweden and Europe to better understand how to effectively use this technology, with some admitting that European processes are lengthy or non-existent compared to other regions. They are eager to learn from best practices in jurisdictions where automated vehicles were deployed years ago.

Public acceptance is another major concern. Interviewees anticipate a mixed public reaction, similar to what was seen with ride-hailing and micromobility services. One interesting perspective is that some elderly people might feel more comfortable with a machine rather than an unfamiliar human driver. Concerns about job displacement also exist, though it is also suggested that robotaxis could improve

poor working conditions. A clear sentiment is that robotaxis should not compete with public transit or increase congestion and that their costs should not undercut transit fares.

Swedish municipalities want robotaxi companies to share data, particularly on the usage of pick-up and drop-off spots. They also advocate for cities to become more digitally literate to effectively integrate these services.

The perspective on robotaxis in Europe differs from that in the U.S. and China. In Europe, the focus is often on boosting industry competitiveness and providing benefits for entire cities, rather than solely on market-driven innovation or individual user convenience. Interviewees consider that the ultimate goal for large-scale robotaxi deployment in Sweden and Europe is to find a middle ground between the traditional public-sector transportation monopoly and a potential corporation-run system. Ensuring traffic safety and promoting shared use to foster sustainability and reduce urban space requirements are key priorities.

5.2. Public transport agencies and operators

Swedish public transit agencies and operators are approaching the deployment of robotaxis with a nuanced and largely cautious perspective. While they are interested in the potential of autonomous vehicle technology, they draw a clear distinction between individual robotaxis and shared autonomous solutions, prioritizing public benefit, economic viability, and seamless integration within existing public transport systems.

Several agencies emphasize that robotaxis, which are by definition for individual and not mass transportation, are not their primary interest, but rather shared autonomous vehicles, such as AV shuttles or self-driving buses. Some explicitly state that operating taxi services is not within their purview, underscoring a commitment to collective mobility. Implied a view that robotaxis may be carrying 1-2 riders only, these organizations are keen on maximizing efficiency with shared vehicles, particularly those with passenger capacity to carry 4-8 persons, to effectively manage transportation needs without increasing the number of vehicles, especially during peak hours.

A consistent theme among these agencies is the objective to reduce private car traffic and increase public transport's market share. They demand that any robotaxi deployment must directly contribute to this goal by encouraging people to switch from private cars to public transit. Some envision shared autonomous vehicles as a revolutionary and sustainable alternative to fixed routes, particularly for first- and last-mile solutions, and specifically mention bus-on-demand services as a complement to existing routes. The motivation for shared AVs also includes addressing the significant problem of driver shortages and improving economic efficiency through purpose-built, driverless vehicles.

When asked about the top priority for large-scale robotaxi deployment, interviewees consistently highlighted public and societal value. Agencies prioritize the economic benefit for taxpayers and domestic corporations as well as sustainability, which has to include that shared autonomous services will not increase the number of vehicles on the streets. They stress the importance of societal value, demanding that deployments be environmentally and economically beneficial for the community. Alongside this, some operators underline that a sustainable business model is a must for any deployment to succeed.

Public transport managers express concerns about the current policy landscape in Europe, noting that regulations, which unilaterally prioritize citizens' well-being but may fail to consider competitiveness and innovation, may deter robotaxi companies from focusing on the European market. They also point out that public agencies often expect AV companies to bear the financial risk of potentially high upfront investments which can further increase the hesitance for the European market.

While acknowledging the significant progress in addressing safety and security concerns, particularly evident in robotaxi deployments in the United States, some European transit operators highlight the

difficulty of changing public behaviors. They do however recognize a risk that robotaxis might simply replace personal vehicle trips without actually reducing overall car usage.

Collaboration is widely seen as essential for successful deployment. Some envision triangle partnerships involving the public transit agency, the public transit operator, and the robotaxi developer, with a vehicle manufacturer and AV stack provider preferably being one entity so that operations remain manageable and do not become too complicated because of too many players involved. Others indicate openness to collaborating and responsibility-splitting with private initiatives like traditional taxi services and ride-hailing or novel robotaxi companies, even if it differs from some European counterparts who aim to own all aspects of the service.

Looking ahead, some agencies are already involved in ongoing bus-on-demand projects and plan to partly replace fixed routes with autonomous vehicles in the coming years. They also anticipate autonomous city buses becoming accessible to the general public, with a mid-term (within a decade) aim for safety drivers to transition to a passenger-facing support role.

Overall, Swedish public transit agencies and operators generally look for autonomous vehicle deployments to complement public transport with shared, sustainable solutions, rather than replacing it. Their priorities are firmly rooted in public benefit, economic viability, and a cautious, integrated approach to deployment, while also acknowledging the need for robust partnerships and adaptable strategies as the technology continues to evolve.

6. Lessons learned – and to be learned

In this chapter, the aforementioned experiences with commercial robotaxi deployments in the United States and China are analyzed in relation to the expectations, targets, and questions expressed by the Swedish interviewees. In general, the Swedish stakeholders would like robotaxis to play a role in society and to contribute to reaching societal targets. This is also true for several European markets, as can be seen in e.g. the CCAM Partnership Strategic Research and Innovation Agenda (SRIA²⁰).

6.1. Lessons to be Learned

The following presents the key questions that stakeholders in Europe / Sweden seem to want answered before large-scale robotaxi deployment. They are grouped by category to highlight areas of focus.

6.1.1. Safety and Security

- How can robotaxis contribute to safer traffic, and how can their safety be proven to be greater than that of human drivers?
- How do people feel about the safety and security of robotaxis, especially without a human operator present?
- How can the contribution of robotaxis to safer traffic be quantified and assessed at a city or regional level?
- What are requirements for an accepted level of safety?

6.1.2. Integration into the Mobility System

- What are the benefits of robotaxis compared to existing public transit options like larger buses or trams?
- How can robotaxis be integrated with public transport and what are successful examples of these combined offers?
- How can it be ensured that robotaxis will be used for shared rides opposed to individually used and do not simply add to traffic and congestion?
- What specific “useful services” can robotaxis provide, particularly in rural areas and for first and last-mile transport?
- How can robotaxis help solve urban parking problems instead of exacerbating them?
- How will mobility behavior change with the widespread use of robotaxis?

6.1.3. Business Models

- What successful business models exist for robotaxis?
- How can the necessary critical mass of users be achieved to attract robotaxi operators to Europe / Sweden?
- How can viable business models be developed for the European and Swedish context?
- Who bears the potentially high upfront cost of implementing a driverless service (mapping, infrastructure, system adaptation and integration)?

6.1.4. Cities’ Roles and Responsibilities

- What is the minimum and ideal roles and responsibilities for a city in a robotaxi deployment?
- How have cities with past deployments handled their roles, both proactively and reactively?

²⁰ <https://www.ccam.eu/wp-content/uploads/2023/11/CCAM-SRIA-Update-2023.pdf>

- What is the ideal interaction between a city and a robotaxi company?
- What is the right balance between national and local decision-making and regulation?
- Is it necessary to regulate the entire service, or may it suffice to regulate on a vehicle level (like type approval), and if so, how?



Figure 6: Zoox, one of the more recent robotaxi operations in San Francisco, awaiting riders with doors open [Sven Beiker]

6.2. Lessons Learned

These are lessons derived from existing robotaxi deployments in the United States and China, which provide valuable insights for future rollouts.

6.2.1. Safety and Security

- It is still not clear how to measure safety of robotaxis. The question “how safe is safe enough” remains unanswered.
- The safety and security of a robotaxi service should be at least as high as that of Waymo, a leading operator.
- Comfortable, thoughtfully designed, small electric robotaxis have the potential to provide levels of security and privacy that many see lacking in conventional public transport, ride-hailing, and taxi services.
- It is crucial to involve first responders early in deployment to help driverless vehicles recognize and react appropriately to emergency vehicles. This is an area that was underestimated in California.
- A sense of feeling more secure in robotaxis than in conventional taxis or buses was expressed by focus groups because no driver or co-rider needs to be feared.

- It is valuable to develop specific reporting requirements for incidents like vehicle immobilizations to proactively identify challenges.
- Robotaxi sensors can be used to develop leading indicators of potential safety hazards, rather than only relying on crash data after an incident.

6.2.2. Integration into the Mobility System

- The ability to offer 24/7 operations is a key benefit compared to existing public transport. Limitations, such as in China, due to economic considerations by the operators are seen as a significant disadvantage in comparison to human driven taxis.
- Waymo's vehicles are omnipresent in their selected deployment areas in the San Francisco Bay Area.
- The number of robotaxi implementations and users in the U.S. and China are currently too small to measure changes in overall mobility behavior.
- Robotaxis may be a potential enabler for people with disabilities, youth, the elderly, and those in rural areas to access services, but evidence is still lacking.
- Some few examples of public transport integration include providing first/last-mile rides to and from train stations, however their financial viability is a major concern.

6.2.3. Business Models

- It is heavily debated whether there are already profitable business cases with robotaxis.
- Pilot programs with a small number of vehicles are not effective for assessing profitability, however the high costs for software, maintenance, and research are a common concern.
- Focusing on areas with a serviceable market of over 500,000 population is seen as a level where business models could become viable. Additionally, a minimum fleet size of a few hundred vehicles is seen as a prerequisite for profitability in China (and potentially elsewhere as well).
- Partnering with a service that already has an existing customer base (e.g., traditional ride-hailing like Uber, Bolt...) can help reduce costs.
- In California and China, transports to and from airports are considered important for a profitable business case as those are high-demand routes with high willingness to pay.

6.2.4. Cities' Roles and Responsibilities

- High levels of city involvement are crucial for successful robotaxi rollouts. China and Arizona are positive examples, otherwise issues arise like evidenced in San Francisco.
- Cities should proactively define what they want to achieve with robotaxis and how the technology can contribute to their goals.
- Cities should actively manage curb sides like designating pick-up and drop-off points, temporary parking, charging etc.
- Early collaboration between cities, robotaxi companies, and public transport authorities is key.

6.3. Takeaways

The lessons learned already provide some direct response or valuable context for the questions being asked:

- **Safety:** Stakeholders question how robotaxis can contribute to safer traffic. One main lesson learned is that involving first responders early on is critical and directly addresses a key safety concern.
- **City Involvement:** Swedish stakeholders want to know a city's role and responsibilities. The lessons learned are clear in that high levels of city involvement are crucial, and they should proactively manage aspects like curb side space and define their goals for deployment.
- **Business Models:** Stakeholders want to know if successful business models exist. Many interviewees state there are currently no profitable models, but existing commercial operations provide insight into what might make them viable, such as operating in areas with high TAM (Total Accessible Market) and partnering with existing services.
- **People involvement:** Successful deployment of any mobility service will only be achieved if used and appreciated by people. In addition to regulators and operators, persons from various demographics and income levels should participate in discussions to ensure services are available, affordable and accessible to a critical mass of users and thereby making robotaxis a viable and sustainable mobility option.

6.4. Open Questions

Some of the questions posed by stakeholders in Sweden have not been adequately answered by current deployments, yet, suggesting a need for further research and investigation.

- **Behavioral Change:** Stakeholders want to know how mobility behavior will change with robotaxis. The lesson learned is that current U.S. and China deployments are too small to measure such a change and pricing is so close to existing ride hailing services that the impact remains a major open question.
- **Quantifying Societal Impact:** While there is evidence that robotaxis can make people feel safer, the broader question of how they contribute to safer traffic and more livable cities has not been documented or quantified. The same is true for impact on other societal ambitions such as climate goals, enhanced traffic efficiency and accessibility.
- **Robotaxi Integration in Public Transit:** Expecting a better business case, robotaxi deployments have apparently focused on individual mobility without much interest in public transport. This leaves open the question of how to develop and realize an integrated transportation system.
- **Regulation of Service:** Stakeholders are curious about the necessity of regulating the entire service, not just the vehicle. The lessons learned do not provide a direct answer to this, leaving it an open question for future discussion and development.

7. Recommendations

Based on the comprehensive analysis of robotaxi deployments, stakeholder insights, and the identified challenges and opportunities, the following recommendations and next steps are proposed to facilitate the successful and socially beneficial integration of autonomous mobility, particularly within European and Swedish contexts.

Several, if not most, of the recommendations in this chapter do require novel thinking and innovative approaches. This means that several of the recommendations below need actions from more than one type of stakeholder. This is also true for the key issue of finding viable business / operating models as well as establishing frameworks to quantify safety and sustainability impacts. It is advised to consider involvement of research organizations when addressing the various recommendations, because those can provide a neutral perspective, largely free of commercial, political, and other strategic interests.

7.1. For municipalities

A city that is considering robotaxis, should first define clear goals as to what should be achieved and from there identify possible robotaxi contributions to urban goals, such as reducing congestion, enhancing public safety, improving accessibility, and supporting climate goals. It is essential that deployment strategies closely align with overarching visions for what an urban environment should look like. Robotaxis might not automatically be the best solution.

In particular:

- Establish how driverless vehicles can contribute to quantitative frameworks for emissions, traffic volume, mode share, travel times, parking capacity, etc.
- Proactively work on how to manage of curb side, pick-up / drop off points, and to make sure that robotaxis will solve and do not add to transport problems in cities. Establish regulatory frameworks.
- Demand performance data from potential robotaxi operators to assess actual impacts on traffic, parking, and overall mobility.
- Work together with PTA, industry (primarily operators), and researchers to align the supply and demand sides for potential robotaxi operations. It is stated that robotaxis require a critical mass of >500 000 citizens.

7.2. For regulatory bodies

Develop proactive and adaptive regulatory frameworks: Establish clear, flexible, and forward-looking regulations that anticipate technological advancements while ensuring public safety and urban livability. Mandate robust safety demonstrations and transparent data sharing (beyond just miles driven, including leading safety indicators) with municipalities and regulators.

In particular:

- Investigate whether it is necessary to regulate not only the vehicle but also the full service, and how to do that.
- Develop specific reporting requirements for incidents like immobilizations to proactively identify challenges.
- Support and contribute to development of lead indicators for potential safety hazards, using the AV sensors and equipment.

7.3. For public transit agencies

Explore integrated mobility services and design services with the purpose to move more people efficiently and conveniently with fewer vehicles. Collaborate with industry (operators, technology (“app”) providers), research organizations, and municipalities to devise an overall approach to address transportation challenges.

In particular:

- Explore and research options for (viable) operating models for the European (Swedish) context, considering whether direct integration with public transport is indeed the primary initial use case; critically check if / how complementary services for specific needs (e.g., first/last mile, underserved areas) can work.
- Identify what constitutes “useful services” to citizens. Initiate development and realization of combined offers and how to effectively integrate robotaxis with public transport.
- Develop viable services for rural populations, and first / last mile solutions.

7.4. For industry stakeholders (manufacturers, operators, technology developers)

Even when assuming technology readiness of robotaxis at a level that allows their deployment at large scale, industry still needs to address several essential elements in order to get to a future of economically, environmentally, and societally sustainable transportation.

- In particular: Embrace operational partnerships: Consider strategic alliances with operational specialists to manage large fleets and focus internal resources on core technology development, as managing extensive fleets may not align with all technology companies' core competencies.
- Develop and validate robust, scalable, and profitable business models. This includes investigating diversified revenue streams, optimizing operational efficiencies, and demonstrating clear economic value propositions that justify large-scale fleet deployments. Focus on achieving critical mass (e.g., hundreds of vehicles per city) to achieve financial sustainability. Establish and standardize safety frameworks: Actively collaborate with regulators, research institutions, and other industry players to develop and advocate for common, data-driven safety standards. Provide regulators and local authorities with leading indicators for potential safety hazards, using the AV sensors and equipment.
- Tailor deployments to local contexts: work with PTAs, municipalities and research organizations to serve true needs. Recognize and adapt to the unique requirements, infrastructure, and traffic conditions of different cities. Engage proactively with local authorities to ensure seamless integration and avoid operational conflicts.

7.5. For research and academic institutions

As stated at the beginning of this chapter, most of the recommendations outlined above do require novel thinking and innovative approaches. It is advised to consider involvement of research organizations when addressing them. One key item where research organizations should take the lead is in quantifying societal benefits of robotaxis (e.g., accident reduction, emissions decrease, accessibility improvements) to inform policy and investment decisions as well as public discourse. Researchers and experts can benefit from experiencing robotaxis available today, across many locations in the United States and China with a spectrum of offerings and settings, to understand pros and cons.

In particular:

- Focus on cross-disciplinary research: investigate the societal impacts of robotaxis, including behavioral changes, equity considerations, and environmental effects. Research should integrate technical, social, economic, and ethical dimensions.
- Devise methods and means to quantify and assess the safety impact of AVs in general and robotaxis in particular. This also needs to include more refined data collection on baseline traffic safety today in order to enable “apples to apples” comparisons.
- Address the lack of documentation of robotaxis’ contribution to safer traffic on a city/regional level.
- Develop lead indicators for potential safety hazards, using the AV sensors and equipment. This would allow to proactively avoid the hazards instead of retroactively collecting crash data.

Annex 1. Methodology details

Information research

The project team conducted comprehensive research on global robotaxi deployments, with a specific emphasis on the United States and China. This research was conducted in two dimensions: (1) targeted searches for specific information, including deployment figures and locations, to provide a comprehensive understanding of the situation as outlined in sections 3 and 4; and (2) opportunistic collection of relevant information through continuous monitoring of the field to incorporate novel developments and perspectives into the overall narrative of this report. Consequently, a substantial collection of research reports, media articles, technical presentations, and corporate communications materials was reviewed and incorporated as appropriate. The resources utilized are listed at the end of this report.

The limited and highly competitive commercial robotaxi deployments have resulted in a scarcity of publicly available studies involving individuals who have utilized such services. Consequently, user experiences are predominantly anecdotal rather than statistically robust. However, the numerous experts consulted by the authors indicated that such specific insights and narratives can provide a reasonably accurate portrayal of the preferences and dislikes of robotaxi users. They also provided examples for incidents and settings that should be addressed in future deployments.

The information research largely formed the content presented in chapter 4. However, because of its scarcity, stakeholder interviews and focus groups play an even more critical role in the findings of this study, potentially more than the facts and information research conducted by the team.

Stakeholder interviews

Both online and in-person interviews were conducted in the United States, primarily in California, as well as in China and Sweden. The participants covered a diverse range of individuals, as detailed in Table 1.

Table 1: Overview of stakeholders interviewed by region

	California	Arizona	Texas	China	Sweden
Regional / state administration	2				
Municipality, airport authority	7	1			5
Manufacturer	4			3	1
Public transit agency					3
Operator, service provider	1				1
Researcher, consultant	4		1	4	
Citizen, not in focus groups	1			2	

The interviews were structured to comprehensively explore various facets of robotaxi implementation, encompassing the underlying motivations, the sequential processes, the significance of partnerships, the public's response to the services, and any areas of robotaxi deployment that were underestimated. In this regard, the interviews conducted in the United States and China concentrated on the lessons derived from robotaxi deployments, while in Sweden, they primarily focused on the anticipated expectations of stakeholders regarding the eventual arrival of those vehicle fleets in their jurisdictions. An outline was crafted to guide the interviews (see Annex 2. Interview questions), yet they frequently deviated from the planned agenda to comprehensively gather specific information pertaining to unforeseen aspects. This demonstrates the current state of the robotaxi sector, which can often be best

described through examples and anecdotes. The interviews were not recorded, and participants were promised anonymity unless they explicitly consented otherwise. The project team maintained written notes that provided input to the findings presented in subsequent sections of this report.

The stakeholder interviews largely formed the content presented in chapters 4 and 5.

Focus groups

As Table 1 indicates, the project team conducted only very few interviews with individual users (“Citizens”) utilizing the prepared interview outline. During those interviews, it was discovered that the experience to be captured was significantly more individual, personal, and anecdotal than what would conform to a strict study protocol. Consequently, it was determined to prioritize focus groups of robotaxi users and non-users to facilitate discussions on their experiences, expectations, suggestions. That way, the study provides a broader perspective to inform stakeholders regarding the desired and undesired aspects of this form of transportation. During these semi-structured discussions, randomly selected citizens, both with and without robotaxi experience, shared opinions, anecdotes, preferences, and suggestions for improvement. Although not statistically representative, these mobility users contributed a diverse and valuable perspective to the study.

Two focus groups were conducted at the end of February 2025, one in San Francisco and the other in Palo Alto, each lasting approximately two hours. The number of attendees is listed in Table 2.

Table 2: Overview of focus groups conducted

	San Francisco, CA	Palo Alto, CA
Date	Feb 26, 2025	Feb 27, 2025
Location	German Hub	Nordic Innovation House
Setting	Roundtable	Workshop, open seating
Participants	7	10

The focus groups also found primarily entry into the content presented in chapter 4.3.

Analysis and review

The study’s information research, stakeholder interviews, and focus groups allow ultimately to draw conclusions and recommendations. Draft insights were developed and shared with stakeholders to gather diverse perspectives and enhance findings. The extended team and interview partners reviewed draft versions of the report or participated in closing meetings to comment on the findings. The project team also paid attention to other projects’ presentations and publications to complement and cross-check the final outcome.

Annex 2. Interview questions

The following are the questions that were prepared for the stakeholder interviews. Not all questions were necessarily asked but rather served as a general guideline to gain insights into robotaxis deployments. The set of questions differed slightly between two groups.

Questions about experiences from robotaxi deployments in U.S. and China

A Operators / municipalities, regulators

- A.1 What is/was the driving force behind the implementation? Who initiated it?
- A.2 How long have the robotaxis been in operation, with how many miles, trips, passengers...?
- A.3 Do you have any objectives for/motivation behind the deployment? If so – what is it?
- A.4 What did the process for the implementation look like?...
- A.5 What partnerships were helpful / essential?
- A.6 What was underestimated in the deployment?
- A.7 What were the reactions from the public?
- A.8 Did sharing of data play any role, and how was it handled in that case?
- A.9 What do you know now that you wish you had known when you launched robotaxis?
- A.10 What are your plans for future services, deployments, partners...?
- A.11 Would you be interested in deployments in Europe / Sweden?

B Users

- B.1 How much have you used robotaxis (since when, approx. number of rides...)?
- B.2 Which services have you used and where?
- B.3 Were you part of an early user program? If so, how were you selected?
- B.4 What was your motivation to use those services?
- B.5 What did you like at the beginning? How did that change, do you still like it?
- B.6 What did you not like at the beginning and did that change?
- B.7 Has your mobility behavior changed through the experience?
- B.8 What do you know now that you wish you had known when you first used robotaxis?
- B.9 Do you find the pricing competitive?

C General, all interviewees

- C.1 Who benefits the most from the services?
- C.2 What should future deployments take into consideration?
- C.3 What needs to be avoided and how?
- C.4 Who else should we talk to?

Questions about expectations toward robotaxi deployments in Sweden / Europe

A Operators / municipalities, regulators

- A.1 Is your community / organization interested in robotaxis; and if “yes”, then “why”?
- A.2 If interested in robotaxis, is that really what you want or is it rather shuttles, AV buses, or else? Why?
- A.3 What can the role of robotaxis be in your area? What would be the driving force behind the implementation? Who would initiate it?
- A.4 What would be objectives for/motivation behind the deployment?
- A.5 What are your ideas about a deployment: Intended scope, time frame? Pilot or permanent? Intended target groups, if any?
- A.6 If you are not planning or foreseeing robotaxi in your area – is there anything that would make you change your mind?
- A.7 If robotaxis “just show up”, like e-scooters did – should anyone react? Who? What should that one do?
- A.8 What would the process for the implementation be like?
- A.9 What partnerships would be helpful / essential for an implementation?
- A.10 How do you think the public would react? The intended target groups? Would it depend on who stands behind the implementation?
- A.11 Anything you would like to pick up from existing commercial deployments? “Lessons to be learned”?
- A.12 Is there a risk of conflicting goals in robotaxi deployments? How would you tackle that?
- A.13 What type of data would be useful for you, and what would it be used for? (lack of data of impact, ...)
- A.14 What are your plans for future services, deployments, partners...?
- A.15 What is your one-word answer regarding what shall be prioritized if deploying robotaxi in large scale in Sweden?
- A.16 In reports, interviews and focus groups there are several items that are frequently mentioned about what needs to be done in preparation of deploying in large scale. Is there anything sticking out in your point of view? Do you consider any of those important for commercial success? Which may be detrimental to commercial success?
- A.17 How important is commercial success of a robotaxi deployment? How would you define it?

B Users

- B.1 Have you used robotaxis (since when, approx. number of rides...)?
- B.2 Which services have you used and where?
- B.3 What was your motivation to use those services?
- B.4 What did you expect? Were expectations met?
- B.5 What did you like? Has that changed, do you still like it?
- B.6 Did you have any concerns before riding? Has that changed?

- B.7 Would your mobility behavior change if robotaxis were available in your area? If not – what would make you replace a personal car with robotaxi service (& PT)? (if you have one)
- B.8 What do you know now that you wish you had known when you first used robotaxis
- B.9 How do you think about pricing of a robotaxi service? What would you be willing to pay for?

C General, all interviewees

- C.1 Who benefits the most from the services?
- C.2 What should future deployments take into consideration?
- C.3 What needs to be avoided and how?
- C.4 Who else should we talk to?



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