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Cross-Industry Perspectives on Automation in Mobility: Analyzing the Current State of Autonomous Driving by Contrasting Expert Insights and Public Perception

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Abstract

How advanced are the automotive, aviation, and Urban Air Mobility sectors in commercializing automated and autonomous mobility solutions? To address this question, this paper assesses different readiness factors, analyzed with insights from industry experts and complemented with findings on public perception, collected through a comprehensive survey. It also provides a cross-industry analysis to identify common challenges and different stages of development. While technically feasible, the solutions face difficulties in addressing edge cases and navigating regulatory requirements. Despite technological advancements, economic viability is not guaranteed. Moreover, public trust, for which familiarity with the technology is crucial, is also important.

Keywords: Automotive, Autonomous Driving, Aviation, Single-Pilot Operations, UAM, Innovation, Automation, Autonomy, Mobility, Expert Insights, Public Perception, Cross-Industry Comparison, Technological Advancements

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1. Introduction

Transportation plays a major role in today's economy and society, significantly influencing economic growth and global employment (European Commission n.d.). Moreover, the industry accounts for 29% of the world's final energy consumption, highlighting its importance in both economic and environmental contexts (Stanford University n.d.). However, within the next decade, the mobility ecosystem is expected to face a significant transformation as, among others, companies are constantly developing new transportation options, thus entering a "new age of innovation" (Heineke et al. 2023). Disruptive trends, especially new technologies will play an important role in this evolution, primarily driven by the rise of artificial intelligence (AI), machine learning (ML), and computer vision (Tepylo, Straubinger, and Laliberte 2023). As a result, the transportation industry will increasingly benefit from these technologies, with vehicles incorporating more autonomous features, that simplify the tasks of driving cars and piloting aircrafts (Tepylo, Straubinger, and Laliberte 2023). This shift, fueled by increasing public demand for more efficient transport options, is aiming not only at enhancing safety but also reducing the potential for human error (Hutchins and Hook 2017; Tepylo, Straubinger, and Laliberte 2023). Nevertheless, technology by itself cannot address the various transportation challenges. Instead, the future of mobility also requires adaptations in governmental processes, effective regulations, and collaboration among agencies, along with support from potential users (Flynn 2023). As Heineke et al. (2023) note, customer preferences hold significant power and are as "equally, if not more important" than technological and regulatory advancements.

This paper examines the implementation of automation technologies across the automotive, aviation, and Urban Air Mobility (UAM) industry. These industries are increasingly adopting automation to transform traditional modes of transportation. The automotive sector is witnessing advancements such as Advanced Driver Assistance Systems (ADAS) (Continental Automotive n.d.). In aviation, autopilot systems have become standard features in commercial flights, enhancing safety and operational performance (Trippe and Mauro 2016). Meanwhile, UAM is preparing to develop autonomous technologies that will revolutionize urban transportation (Yan, Wang, and Qu 2024). Despite these significant advancements, the full potential of autonomous cars, highly automated, crew reduced airplanes, and autonomous passenger drones has yet to be realized. Consequently, this paper aims to explore current state and evolution of certain forms of automation in these three industries that are sufficiently distant to still face uncertainty. At the same time, their advancements are feasible within a foreseeable timeframe and the underlying technology is already at an assessable stage of development. As the landscape constantly evolves, this thesis will provide a comprehensive analysis of the current state of automation within these industries, ranging from well-established to emerging, and compare expert insights with public perception across all three sectors. Moreover, by analyzing these three industries collectively, this paper seeks to offer a cross-industry comparison, highlighting commonalities, differences, and potential learning effects.

The thesis is divided into nine chapters. After these introductory words, the second chapter explores the impact of automation technologies and introduces the factors by which the current state of automation in each mobility sector is later evaluated. The approach and methodology, for which various expert interviews and a survey on the public perception of autonomous technologies were conducted, are presented in chapter three. In the following, the subsequent sections offer a closer examination into the different industries. This includes a general overview, a literature review, highlighting past research within each industry, and the empirical analysis. The latter focuses on delivering the results of both the expert interviews and the conducted survey. These individual sections are followed by a discussion across all three industries and a presentation of the study's limitations and opportunities for future research. Ultimately, chapter nine provides a conclusion of the findings.

2. Automation and Autonomy in Transportation

2.1 Automation Technologies

The progression of automation across various modes of transportation is revolutionizing mobility by reshaping the movement of people and goods (Karami, Karami, and Mehdizadeh 2023). This shift is driven by the growing demand for safer, greener, and more efficient transportation, which highlights the urgent need to increase the level of intelligence of existing systems (Jia et al. 2022). Leveraging advances in fields such as AI, cyber-physical systems, cloud computing, and communication networks, automated and autonomous transportation systems aim to minimize human involvement and support autonomous perception and decision-making (Jia et al. 2022). At its core, automation refers to "the use of various control/sensor systems and actuators to operate machines, reducing the need for human intervention" (Campilho and Silva 2023). While these control systems and technologies also have a significant impact on production and manufacturing processes, this paper will solely focus on their implications for mobility operations and the aircraft/vehicle itself. Whereas automation involves systems designed for specific, predefined tasks that require some level of human supervision, autonomy refers to systems capable of operating independently without any human intervention (McClean 2021). Autonomous systems are able to learn, adapt to dynamic environments, and respond to unexpected hazards, achieving fully self-sufficient operation (McClean 2021). Distinguishing between automation and autonomy is important for understanding the difference between the advanced technologies discussed in this paper. Autonomous transportation systems are the next step in mobility evolution and represent a complex system of systems that integrates multiple intelligent subsystems, such as vehicles, infrastructure, and environment, all working together to achieve high safety, efficiency, and resilience (Jia et al. 2022). Unlike isolated automated functions, an autonomous transportation system operates as a fully connected network, leveraging deeply integrated technologies that enable functions like self-perception, self-adaptation, and self-decision-making. These capabilities allow the system's components to respond dynamically to changing conditions, offering autonomous transportation networks that go beyond individual vehicle automation. An ideal interconnected autonomous transportation system would see traditionally human-held roles transferred to vehicles, infrastructure, and other system components. This shift would create a cohesive system in which vehicles and infrastructure collaborate seamlessly, allowing the entire system to adapt to the transportation environment (Jia et al. 2022).

This transition from automation to full autonomy offers significant benefits (Pretlove and Royston 2023) with advancements like self-driving cars and self-piloting aircraft both aiming to reduce accidents, improving safety. However, achieving full autonomy involves critical challenges such as addressing trust and safety concerns, maintaining data privacy, and ensuring ethical standards (McClean 2021). Legal liability is another complex concern, which raises questions about responsibility, ownership, and insurance when autonomous systems make independent decisions (Brożek and Jakubiec 2017; McClean 2021). As systems become more autonomous, clarifying legal accountability is essential to protect passengers, manufacturers, and companies, making this a critical issue that demands regulatory attention. To address all these challenges, global organizations, academic institutions, and governments are actively working on solutions (McClean 2021). This effort is essential for building the trust needed for a full transition to autonomous systems that can operate without human intervention while still being able to communicate their reasoning and potential limitations.

2.2 Readiness Factors

To draw conclusions about the current state of each automated and autonomous transport solution covered in this paper, different factors will be assessed: the current technological advancements making these solutions possible, the current regulatory framework that allows, restricts or even prohibits the commercial use of these solutions, and the current public perception towards the solution.

First and foremost, technological innovation is the essential foundation for realizing the potential of highly automated or autonomous modes of transport. New and emerging mobility solutions are enabled by and depend on key technologies (European Parliament 2016). However, as stated by Heineke et al. (2024), "innovation does not happen overnight", requiring significant funding from external investors and intense testing. Moreover, successful large-scale implementation of these technologies requires transport and digital infrastructure that has been adapted to support them accordingly (European Parliament 2016). Therefore, evaluating both the technological advancements and the supporting infrastructure is crucial in determining whether these solutions can be scaled for commercial use.

Moreover, this technological readiness cannot be fully realized without aligning with appropriate regulatory frameworks (Aghion, Bergeaud, and Van Reenen 2021). The OECD differentiates regulations between three different categories: economic regulations, social regulations, and administrative regulations. The regulations concerning automated and autonomous transport solutions fall into the category of social regulations as they are meant to protect public interests including health and safety while the economic effects of these regulations are only a secondary concern (OECD 1997). Social regulations in sectors with a lot of room for ethical elements, like transportation, have a strong impact on innovation, as the actions of the parties involved are strongly constrained by them. This means that policy makers have certain power as they are able to prohibit innovations including automated mobility solutions if they are not meeting safety standards and being considered too risky. However, these regulations are also likely to increase public acceptance of new innovations as consumers are confident that regulations always provide a minimum level of safety (Blind 2011). Wiener (2004) suggested in 2004 that risk regulation, back then, may have been at a stage similar to the late 19th century, when it was still unclear whether medical treatment was more helpful than harmful. The same could apply for automated and autonomous mobility solutions, as there are still major safety concerns, however these solutions might one day improve safety significantly by reducing the room for human error. To conclude, it is essential to understand the regulatory landscape to assess the current state of these highly modern mobility solutions, as regulators hold significant power to shape innovation pathways and even public acceptance.

The public also holds a certain power when it comes to the establishment of new technologies. The challenge of balancing technology with user needs is essential for any development in the transportation sector. Aligning technological advancements with user requirements and social acceptance remains a significant hurdle. This underscores the importance of realistic business models to support the progress of automation, considering automation not only as a technological, but also as a social challenge. Adoption of automation technologies, particularly of autonomous vehicles (AV), typically follows an S-curve pattern, with gradual initial progress that accelerates as social acceptance and technological capabilities advance to fully meet user needs (Zarwi, Vij, and Walker 2017; Yannis, n.d.). The perception shapes the reception of an innovation or technology which can determine its success in society. During COVID-19 for example, tracking applications in the US and UK were not adopted by society, which can be partially accredited to the public's distrust in location-tracking technology (Swindells 2021). This power also extends to the automotive industry, where the lack of public trust is seen as the main challenge for commercial adoption of AVs, pressuring car manufacturers to find ways to positively shape the public perception towards this innovation (Kaur and Rampersad 2018). Similar applies for advanced aviation technologies, where the commercial adoption of UAM, in order to be successful, would require a lot more public trust than is currently the case (Tepylo, Straubinger, and Laliberte 2023). But also, for the adoption of highly automated aircraft cockpits with a reduced number of pilots in traditional commercial flights, the lack of public trust is argued to be a major challenge to overcome (Moehle and Clauss 2015). To conclude, public perception of and trust in innovation is highly important when evaluating the readiness for commercial use. The past shows that distrust of a certain technology can severely affect the success or even the establishment of a technology or innovation.

3. Methodology

At this point, several empirical studies explore the status and public perception of automated and autonomous technologies in the automotive, aviation, and UAM industries, as described in the industry specific chapters. However, a comprehensive cross-industry comparison has yet to be conducted, offering a more complete understanding of how automation is progressing differently across these industries. Therefore, we use a mixed-methods design that combines both qualitative and quantitative data. This holistic approach integrates expert interviews as the qualitative component and a survey as the quantitative component. This allows for an in-depth analysis of the current state of automation and a comparison of perspectives between industry experts and the general public.

3.1 Data Collection

3.1.1 Expert Interviews

The primary objective of the expert interviews was to assess each industry's specific challenges, as well as current developments and future expectations. In total, we conducted 24 semi-structured interviews (see interview guide in Appendix A.3) with experts from the automotive, aviation, and UAM industries. These interviews were conducted via Microsoft Teams or in a written format. The online interviews lasted between 30 and 60 minutes. The open nature of semi-structured interviews along with open-ended and individual follow-up questions, if possible, facilitated proactive responses and allowed for in-depth exploration of certain topics (Saunders, Lewis, and Thornhill 2023; Aberbach and Rockman 2002).

3.1.2 Online Survey

The online survey provided additional insights into public perception and acceptance of automation technologies in these industries. The survey was created and administrated using the online tool Qualtrics. It was designed to gather an efficient overview and initial evaluation of the social acceptance factors across the three industries. Out of 241 responses collected, 215 qualitative sufficient responses were used for further analyses. The full questionnaire can be found in Appendix A.4. The survey was distributed online via different social media channels.

3.2 Data Analysis

3.2.1 Analysis of Expert Interviews

Qualitative content analysis was selected as the methodological framework to interpret the interview data, following the structured and systematic approach developed by Mayring

(2000). Given the research focus, Mayring's method provides a clear, rule-based approach for organizing and categorizing complex information. This approach aligns well with our aim to uncover industry-specific insights while capturing recurring topics, which reflect common claims made by different experts. By using predefined criteria, we systematically coded the data to identify patterns while preserving essential information, making it possible to reduce and generalize findings without sacrificing depth. The interview data was analyzed using categories that align with the sections outlined in the questionnaire. These categories are:

- Industry Readiness & Technology Advances
- Impact on Human Roles & Employment
- Regulatory Framework & Safety
- Public Perception & Trust in Automation
- Future Outlook & Strategic Vision
- Comparative Analysis.

To further analyze the interviewees' responses, inductive codes, distinctive for each industry, were developed. These individual codes provide a structured foundation for examining the critical factors influencing the development and implementation of each automated or autonomous transport solution. The reduction was particularly important as it allowed us to extract industry-specific insights on automation from a wide range of expert views while maintaining comparability across sectors. Thus, this method provides a clear framework for integrating diverse perspectives while ensuring that the analysis remains focused on the overarching research objectives, making it an ideal approach for this study.

To support validity and minimize interviewer bias, a structured interview guideline was developed in advance to ensure consistency and increase objectivity (Kuß, Wildner, and Kreis

2018). Finally, transparency in the research process was maintained through comprehensive interview transcripts and a systematic coding process. For clarity and simplicity, experts will be referenced in the text using an abbreviation followed by "_EX," with "X" representing the numerical identifier assigned to each expert within their respective industry (“AV_EX” for autonomous vehicles experts, “SiPO_EX” for single-pilot operations experts, “UAM_EX” for autonomous urban air mobility experts). All systematic interview reductions can be found in Appendix A.3.1.

3.2.2 Analysis of Online Survey

Conducting the survey was essential to gain a broader perspective, with public opinion providing insights into societal acceptance, concerns, and attitudes towards automation and autonomy. This complements the industry-focused views obtained from experts. To achieve a comprehensive understanding, a combination of Likert scales and multiple-choice questions was used, as recommended by Kuß, Wildner, and Kreis (2018) for reducing dropout rates and maintaining participant engagement. Participants rated key statements on a five-point Likert scale, allowing us to measure levels of importance for detailed statistical analysis. An odd-numbered scale was intentionally used to give respondents the option of a neutral response, ensuring that they were not forced into a polarized response (Porst 2013). In contrast, the multiple-choice questions were designed as short, close-ended items with predetermined response categories, which simplified responses and contributed to a higher completion rate (Kuß, Wildner, and Kreis 2018). To address the limitations of close-ended questions, participants were able to add their own responses, allowing for the capture of unique perspectives not initially covered by the predefined choices (Kuß, Wildner, and Kreis 2018). Demographic data were collected at the end of the survey. This structure was intentional, as demographic questions can sometimes lead to participant reluctance (Yan 2020).

For the quantitative part of the study, data reliability has been ensured through standardized survey questions, allowing for consistent responses across all participants (Zillich et al. 2024). All visualizations related to the survey results, are included in Appendix A.4.3.

4. Autonomous Driving

4.1 Industry Overview

The global automotive industry, valued at USD 3.6 billion in 2023, continues to be a significant driver of the world economy, contributing heavily to industrial output and employment (Spherical Insights 2024). The projected compound annual growth rate (CAGR) of 4.5% for the automotive industry from 2022 to 2030 is supported by multiple sources, emphasizing factors such as the increasing demand for vehicles, advancements in technology such as electric vehicles (EV) and AVs, as well as customer consciousness on environmental and safety issues (Contrive Datum Insights 2024).

In 2023, nearly 60 million vehicles were produced, with Asia, particularly China, dominating the market with over 57% of the global total. China alone accounted for about one-third of worldwide vehicle production, followed by the United States (Statista 2024). Beyond vehicle manufacturing, the automotive industry impacts several other sectors such as steel, electronics, and chemicals, further underscoring its critical role in global industrial growth (IW 2024). Despite Asia's dominance, Germany remains a key player as Europe's leading market producer, particularly in premium and advanced engineering segments (GTAI 2022). The German automotive industry generated approximately EUR 564.2 billion in revenue in 2023 and employed over 780,000 people directly, with millions more employed indirectly (Statista 2023; IW 2024). However, production has been declining since 2018, with 2023 output levels mirroring those of the mid-1980s. In 2023, Germany produced 4.1 million vehicles, an 18% increase from 2022 but still 12% below pre-pandemic levels (VDA 2024). Despite these challenges, Germany's strong export base, with about 75% of production shipped abroad, remains a key strength (IW 2024).

4.2 Motivation, Implication, and Regulation

The automotive industry is undergoing profound changes, driven by four key trends, enabling a future that “will be PACE – Polarized, Automated, Connected and Electrified” (Roland Berger 2023). These trends are significantly reshaping the industry's landscape and are projected to continue influencing its evolution. This includes various advancements in automation such as innovations in manufacturing processes. However, the following analysis specifically focuses on evaluating the industry's readiness for Level 4 autonomous vehicles.

To understand autonomous vehicles, it is important to first examine ADAS which involves various technologies designed to enhance driving by making it safer, easier, and more comfortable. These systems range from basic features, such as collision warnings, to more sophisticated capabilities, like automatic lane changes (Mobileye 2023). ADAS is specifically designed to support the driver, not replace them. Research, including a study by Yue et al. (2018), has shown that ADAS can have a significant positive effect on road safety (Sanguinetti, Kurani, and Davies 2023). Building on this foundation, the shift toward higher levels of vehicle autonomy seeks not only to reduce human errors—the leading cause of accidents—but also to transform transportation systems, enhancing mobility, increasing road capacity, saving fuel, and lowering emissions (Fagnant and Kockelman 2015).

Additionally, the trend towards autonomous driving also incorporates connected vehicles. This concept integrates advanced communication technologies and therefore enhances interaction with other vehicles, infrastructure, and external networks. A connected vehicle is defined as one that can “connect to the internet and share [data] with devices inside and outside the car as well as external devices/services” (HTEC Group 2023). These vehicles use communication technologies like Vehicle-to-Vehicle (V2V) to share traffic and road condition data, Vehicle-to-Infrastructure (V2I) to connect with city systems, Vehicle-to-Cloud (V2C) for diagnostics and updates, and Vehicle-to-Pedestrian (V2P) to detect pedestrians and avoid collisions (HTEC Group 2023). Together, these technologies form Vehicle-to-Everything (V2X) and create an integrated communication network. The integration of connectivity technologies is a supporting factor in the development of AVs, which are defined as those that use technology to “partially or entirely replace the human driver in navigating a vehicle while avoiding road hazards and responding to traffic conditions” (Center for Sustainable Systems University of Michigan 2024). To better understand the concept of AVs, the SAE J3016 classification system outlines five levels of driving automation, ranging from Level 0 (no automation) to Level 5 (full automation), where vehicles can operate autonomously under all conditions without human input (see Appendix A.1) (SAE International 2021). At Level 5, vehicles are fully autonomous, capable of performing all driving tasks independently, whereas Level 4 vehicles are also highly automated but limited to specific operational conditions and cannot operate universally (SAE International 2021). Subsequently, connectivity and autonomous driving are transforming the automotive industry by fundamentally altering how vehicles function, communicate, and integrate into broader transportation systems.

Germany has taken notable steps in the development of autonomous driving, becoming one of the first countries to legalize Level 4 (high automation) vehicles on public roads in 2021. This milestone was enabled through legislation developed by the Federal Ministry for Digital and Transport, which built upon the Act on Automated Driving from June 2017 (Federal Ministry for Digital and Transport 2021). These national regulations are further detailed in the technical ordinance known as the AFGBV, which provides specific guidelines for the approval and operation of AVs under the 2021 law (Kraftfahrt-Bundesamt n.d.). Looking ahead, Germany plans to incorporate Level 4 and higher AVs, such as self-driving trucks and connected driving technologies, into its transportation system by 2030 (Forvia 2024). Additionally, Hamburg aims to introduce autonomous shuttles as part of its mobility initiatives by 2030 (Volkswagen Group 2024). Germany has developed several strategic test fields to advance the infrastructure required for autonomous driving, spanning both highways and urban environments. Among these, three major projects stand out for their contributions and unique focus areas. The Digital Test Field Autobahn, established in 2015, spans 140 kilometers of the motorway between Munich and Nuremberg, serving as a real-world laboratory for automated and connected driving with LTE coverage, roadside units for high-speed Wi-Fi, and marked lanes for precise localization (BMDV 2024). In Lower Saxony, the Testfeld Niedersachsen, launched in 2020, covers 280 kilometers around Braunschweig, Wolfsburg, and Hannover, focusing on mixed urban and rural testing with an emphasis on V2I communication and real-time traffic management (MWK Niedersachsen 2020). Similarly, Baden-Württemberg's Testfeld Autonomes Fahren, operational since 2018, facilitates autonomous driving research in city and suburban settings, highlighting traffic safety, data collection, and public acceptance (TAF-BW 2024). These projects advance Germany's autonomous driving infrastructure by enabling diverse testing and shaping future standards and safety protocols. Moreover, Germany has made significant progress in 5G deployment with operators using frequency bands to enhance service availability (RCR Wireless News 2024). National initiatives such as the Digital Strategy and Gigabit Strategy of 2022 aim for full fiber optic and 5G coverage by 2030, supported by the 5G Strategy for Germany launched in 2017 (European Commission 2024). Challenges remain in rural areas, but innovations like Vodafone's dynamic spectrum sharing are helping to close the urban-rural connectivity gap (RCR Wireless News 2024).

At the European level, the regulatory framework for automated and driverless vehicles is part of a broader strategy designed to promote the safe deployment of these technologies while maintaining the competitiveness of the European automotive industry. A central element of this framework is the Vehicle General Safety Regulation (GSR), implemented in 2022, which mandates features like intelligent speed assistance, lane-keeping systems, and automated braking by 2024. These rules also lay the groundwork for the adoption of rules governing Level 3 and Level 4 AVs (European Commission 2022). Beyond the European Union (EU), the United Nations Economic Commission for Europe (UNECE) standards offer an international perspective, focusing on broader issues such as cybersecurity, system safety, and human-machine interaction. These guidelines aim for global alignment, ensuring that automated vehicle safety standards are harmonized across countries (UNECE 2022). While the EU’s GSR addresses specific regulatory needs within Europe, the UNECE guidelines provide a technology-neutral framework that supports international coordination in the development of autonomous driving technologies (European Commission 2022; UNECE 2022). Germany's position as Europe's leading automotive manufacturer, with its strong focus on R&D, makes it an ideal example to examine these developments, primarily in the area of increasing automation and the interplay with connectivity (GTAI 2022). The industry’s strong focus on quality, innovation, and engineering expertise, combined with its significant contribution to the national economy, makes Germany the choice for evaluating the readiness for automation within the automotive sector. As noted above, Germany’s pioneering regulatory framework, including its allowance of Level 4 autonomy on highways, reinforces its commitment to supporting advancements in autonomous driving.

4.3 Literature Review

4.3.1 Current State of Technology

To ensure safety and reliability, accurate positioning systems must be developed to handle uncertainties like pedestrian actions, random objects, and different types of roads. AVs rely on several advanced technologies to operate without human help. Zhao, Liang, and Chen (2018) and Parekh et al. (2022) identify key challenges in AV technologies, including sensor limitations, real-time data processing, and cybersecurity. Tan et al. (2024a) highlight advancements in computer vision and AI, emphasizing the critical role of image processing and sensor technologies for successful AV deployment. Research underscores progress in car navigation, path planning, environment perception, and vehicle control, while noting persistent challenges in achieving full industry readiness for such technologies. Car navigation systems rely on GPS and digital maps for route planning and tracking. Hybrid positioning systems, combining gyroscope sensors and GPS, improve accuracy in weak signal conditions (Zhao, Liang, and Chen 2018). Sensor fusion and simultaneous localization and mapping techniques enable navigation in dynamic environments like busy streets, though environmental factors, such as weather, limit reliability (Parekh et al. 2022). Implicating that while advancements in sensor fusion are significant, they are not yet sufficient to handle highly dynamic or adverse environmental conditions. Tan et al. (2024a) recommend incorporating AI and sophisticated image processing techniques to enhance positioning accuracy and environmental perception, aiming to boost the safety and reliability. Path planning determines optimal driving routes using algorithms like Dijkstra and Bellman-Ford but faces performance challenges at high speeds (Zhao, Liang, and Chen 2018). This underscores the ongoing need for research into more robust algorithms capable of operating under such demanding conditions. According to Parekh et al. (2022), real-time path planning and collision avoidance in AVs rely on computationally intensive decision-making algorithms but face significant challenges due to the lack of real-world testing and data. The paper furthermore highlights that proposed algorithms are often not implemented or tested under real traffic conditions, leading to potential inaccuracies and discrepancies in pedestrian orientation and behavior prediction (Parekh et al. 2022).

Research by Zhao, Liang, and Chen (2018) emphasizes that the environment perception ability of AVs highly depends on multi-sensor fusion using laser, radar, and visual sensors to detect road edges and traffic signs. Moreover, Light Detection and Ranging (LiDAR), cameras, and ultrasonic sensors provide a comprehensive view. However, Parekh et al. (2022) underline that adverse weather conditions can reduce sensor reliability. Furthermore, the high cost of LiDAR technology complicates its widespread adoption (Parekh et al. 2022). Tan et al. (2024a) emphasizes improving sensor accuracy and leveraging AI for enhanced obstacle detection. Vehicle control systems manage speed, steering, and braking through Electronic Control Units (ECUs), processing sensor data to execute commands (Zhao, Liang, and Chen 2018). Additionally, existing literature highlights that ensuring cybersecurity is vital to prevent interference with these systems (Parekh et al. 2022). While progress in navigation, perception, and control systems is evident, advancing sensor technology, AI integration, and cybersecurity remain critical for achieving scalable and reliable AV operations.

In addition to the technological readiness, the infrastructure needs to be considered as mentioned above in chapter 4.2. Test fields for AVs are already operational in Germany. However, as Othman (2021a) highlights, modifications to existing infrastructure are essential to support AVs. The paper discusses necessary changes in geometric road design, pavement structures, and bridge engineering, noting that current infrastructure is often incompatible with AV operations. It emphasizes the need for comprehensive planning, investment, and interdisciplinary collaboration among engineers, urban planners, and policymakers to ensure safety and facilitate AV integration into transportation systems.

Cucor et al. (2023) present a framework for evaluating digital infrastructure readiness for connected and automated vehicles. The methodology assesses key factors such as real-time traffic data, communication network performance (latency and bandwidth), and environmental information to identify gaps in meeting technical standards like precise localization and low-latency communication. The paper also highlights segments that require telecommunication upgrades, aiding strategic infrastructure improvements. Additionally, the study emphasizes systematic assessments to ensure that digital infrastructure supports the integration of connected and automated vehicles, enabling safer and more efficient transportation systems.

The literature review identifies significant advancements as well as ongoing challenges in both technology and infrastructure that impact the deployment of AVs. While substantial progress has been made, the comprehensive integration necessary for widespread adoption is still evolving, characterized by the need for enhanced sensor technologies, cost reductions, improved data availability, and substantial infrastructural upgrades.

4.3.2 Public Perception

Understanding public perception is critical for the implementation of autonomous driving, as societal acceptance ultimately determines the real-world viability of AV technology (Othman 2021b). Othman (2021b) found that safety is the foremost concern, with skepticism about AVs' reliability in unpredictable scenarios. Ethical dilemmas, such as decision-making in life-or-death situations, and legal uncertainties regarding liability further challenge acceptance. Furthermore, demographics play a significant role in shaping perceptions. Studies indicate that young, educated urban males are the most receptive to AV technology, often associating it with increased safety and expressing fewer concerns (Anania et al. 2018; Nielsen and Haustein 2018). This group also demonstrates a higher willingness to adopt AVs, though their riskier behaviors may increase accident potential (Hulse, Xi, and Gallea 2018). These young enthusiasts are optimistic, with 56.8% believing in AVs' safety potential, compared to only 7.4% of skeptics (Nielsen and Haustein 2018). Familiarity with AVs also improves perception, as concerns tend to decrease with exposure (Sanbonmatsu et al. 2018). A study by Tan et al. (2024b) in China further highlights the link between knowledge and support for AVs. Surveying over 4,000 participants, the study found that scientific literacy and self-assessed understanding of AVs significantly increase support. Those with greater objective knowledge expressed higher acceptance, suggesting that education and awareness campaigns could be effective in fostering public trust and support. Building on these findings, the following empirical analysis examines the dynamics of public perception and expert insights to evaluate the implementation of AVs.

4.4 Empirical Analysis

4.4.1 Expert Interview Results

Technological Progress and Challenges - Nine experts from the automotive industry were interviewed to analyze the current state of autonomous driving. This technology has achieved significant advancements, particularly with Level 3 systems in premium vehicles and the operational testing of Level 4 systems in controlled environments limited to geofenced areas, which are designated zones where operation is confined within predefined geographic boundaries. Experts highlight the sophistication of current technologies, with progress in sensors, software integration, redundancy, and V2I communication significantly enhancing functionality. As one expert notes, “many key components necessary for Level 4 systems are already in place and well-developed” (AV_E1). However, broader deployment faces challenges, such as addressing complex edge cases, ensuring reliable performance across diverse environmental conditions, and reducing system costs for commercialization. In this context, advancements in AV technology focus heavily on enhancing reliability and safety, with sensor technology playing a critical role. The integration of cost-effective single-camera systems with robust multi-sensor setups illustrates the complexity of sensor design. Improved sensor accuracy, paired with ML algorithms, is essential for improved recognition and decision-making capabilities – key to addressing challenges in AV deployment, aligning with Zhao et al. (2018) and Parekh et al. (2022). Another priority is technological adaptability, with efforts centered on advanced simulation technologies. As AV_E5 explains, "the first major shift is towards virtualization and the use of advanced simulation technologies to simulate millions of driving scenarios digitally," enabling more robust testing in diverse conditions. Simulation technologies also help address edge cases and reduce reliance on pre-mapped data and teleoperation, which remain barriers to reliability, particularly in extreme conditions (AV_E6). Virtual testing enhances the ability to manage these complex scenarios, paving the way for Level 4 scalability beyond geofenced areas. In parallel, cloud-based updates and real-time data sharing contribute to collective system learning and safety improvements, further advancing operational readiness. Pilot projects in cities such as Shenzhen and San Francisco demonstrate localized success; however, scaling remains constrained by infrastructure needs. As AV_E6 highlights, expanding deployment requires solutions that handle unpredictable environments while ensuring reliability.

Human Factors and Workforce Changes - Besides technological limitations, workforce requirements for autonomous driving are undergoing a fundamental shift, necessitating advanced skills in software engineering, data science, and system integration. Experts point to the increasing importance of interdisciplinary skills that combine traditional automotive knowledge with AI and ML to address the shift from mechanical to software-driven functionalities. AV_E1 notes that "the workforce will require a significant shift in skills and competencies, particularly within the automotive industry." Data management and processing is also crucial, as handling large data sets is essential for training robust and adaptive autonomous systems. Cybersecurity is a major concern, with specialists needed to protect against breaches, as highlighted by expert AV_E2. The industry also requires adaptability and problem-solving skills to cope with rapid technological change. According to AV_E4, "skills in human-machine interface and cognitive sciences will become increasingly important." In addition, as autonomous technologies advance, sales and marketing roles are evolving to build trust and effectively communicate benefits, with AV_E7 highlighting the need for skilled salespeople to "connect emotionally with customers."

Cost Considerations - Another significant barrier to the success of autonomous driving is the high cost, primarily driven by the expense of advanced components and system redundancies. While these features enhance safety, they also impact affordability, as AV_E1 notes. These cost challenges limit the technology's accessibility, as AV_E3 points out, "if the technology is too expensive, it will only be available to a small group of people." Affordability becomes more practical in shared mobility services, such as robo-taxis, as AV_E6 explains. This makes shared services "much more practical for shared mobility services, like robo-taxis, where the vehicle is in constant use and the costs can be spread out" (AV_E6). Beyond this, economic pressure, particularly in Germany, compounds the issue, with AV_E3 noting that limited R&D resources further challenge progress in overcoming these cost barriers.

Safety and Reliability Concerns - A further critical challenge in advancing autonomous systems lies in data collection, which is essential for addressing complex scenarios and edge cases – „rare, unpredictable scenarios" (AV_E6). AV_E1 emphasizes, "building real-world datasets through large-scale deployment of autonomous systems will be essential for advancing safety and reliability." High-quality, diverse datasets enable systems to navigate rare and unpredictable conditions. AV_E3 points out that "the quality and diversity of driving data remain challenges, as routine scenarios dominate, while rare and complex cases needed for training are in short supply." AV_E4 adds that "there is a need for massive datasets to validate autonomous systems across millions of different driving scenarios," underlining the resource-intensive nature of such efforts. Addressing edge cases, such as sudden pedestrian movement, requires robust validation to ensure safety and compliance. As AV_E8 notes, manufacturers must demonstrate that these systems are "demonstrably safer than human drivers."

In addition to the edge cases, weather conditions such as heavy rain, fog, snow and glare also significantly affect the reliability and performance of sensors in AVs. AV_E1 notes that these conditions are "challenging even for human drivers." AV_E3 adds that "sensors such as cameras, lidar and radar can be affected by adverse weather conditions," highlighting the need for technological improvements also in challenging conditions like tunnels and rain (AV_E5). Overcoming these challenges is essential to handle unpredictable situations and improve reliability of autonomous systems.

Regulatory Challenges - The fragmented regulatory landscape is hampering the development of AVs, particularly in Germany and the EU. AV_E1 points to the complexity caused by the need for agreement between Germany's 16 federal states, which slows progress. In addition, the lack of a unified framework at EU level further delays deployment. Global alignment is also slow, with frameworks such as UNECE not expected until 2026 (AV_E1). Restrictions such as Europe's small-series production limits further scalability and commercialization (AV_E3). Experts emphasize the need for "standardized regulations across regions" (AV_E3) to streamline processes, enable cross-border operations, and support broader adoption. In Europe, stringent safety-focused frameworks slow innovation and complicate cross-border scalability (AV_E1). The US accelerates deployment with flexible state-level self-certification models but risks inconsistent safety standards, while China's centralized approach facilitates rapid implementation through urban testing zones

. In contrast, Germany's regulatory framework, including the AFGBV Level 4 Act and Kraftfahrt Bundesamt processes, provides a strong foundation for operational and safety standards (AV_E1). AV_E3 emphasizes that this system ensures rigorous testing and aligns with Europe's safety-focused approach. However, further adaptations are needed to expand its applicability and facilitate deployment across different domains. Key areas for improvement include clear liability frameworks, data privacy measures for real-world testing, and protocols that accommodate rapid technological advancements (AV_E4). Balancing strict safety standards with innovation flexibility is critical (AV_E2). Collaborative efforts among policymakers, manufacturers, and regulators are essential to harmonize standards, address liability, and enable scalable deployment across regions.

Public Perception and Trust - An analysis of public expectations regarding autonomous driving reveals a clear emphasis on safety and transparency, as already examined in the literature review. AV_E1 adds that "there is an unrealistic expectation from the public that autonomous systems will deliver a perfect safety record." Clear communication about benefits and limitations is crucial, as AV_E4 emphasizes. Highlighting societal benefits like improved mobility and reduced congestion, as well as transparency in communications are crucial for fostering public trust. At the same time, in addition to the benefits, the limitations of these technologies should also be communicated. AV_E1 identifies trust and acceptance as critical challenges, with skepticism about decision-making systems and traffic concerns persisting. Younger generations tend to view automation as a symbol of progress and innovation, while older demographics often approach it with greater hesitation, as AV_E5 points out. To address these divergent attitudes, AV_E4 emphasizes the importance of clear and consistent communication to set realistic expectations and foster trust. In Germany, public skepticism remains pronounced, driven by concerns about safety, job displacement, and liability issues, as noted by AV_E6. Addressing these concerns requires a proactive approach that combines public education campaigns with transparent dialogues about both the societal benefits and challenges. Gradual rollouts and pilot projects in Europe, as AV_E9 notes, can be effective in addressing safety concerns while demonstrating real-world advantages. Key challenges include demonstrating reliability through rigorous testing in both controlled and simulated environments to ensure systems perform effectively under diverse conditions (AV_E4). Building on these insights, public perception of autonomous driving is shaped by a mix of skepticism and cautious optimism, influenced by generational, cultural, and safety-related factors. Addressing these safety concerns, alongside ethical and customer trust issues, is fundamental to advancing adoption and ensuring the success of autonomous systems.

Integration and Infrastructure Challenges - Adding on that, integration challenges are a significant barrier to autonomous driving adoption. AV_E1 highlights the critical interplay between technology, infrastructure, and regulations, stating that "one of the most significant challenges lies in the interplay between different streams necessary for the successful adoption of autonomous driving." Infrastructure gaps significantly hinder the scalability of AVs, particularly in non-urban areas. AV_E1 notes that "autonomous vehicles require advanced infrastructure, including reliable communication systems and urban adaptations." AV_E2 furthermore emphasizes that "the lack of suitable infrastructure is already a challenge for Level 3 systems, making scaling Level 4 systems even more difficult." In Germany, limited infrastructure readiness further constrains progress (AV_E2). Upgrades like 6G connectivity and V2I communication are additionally essential for the digital infrastructure, as AV_E3 highlights, while AV_E5 stresses the need for clear standards in V2I and V2V systems for seamless operations. Addressing these gaps through infrastructure improvements is vital for enabling widespread adoption.

Future Development - A look at the dynamics of autonomous driving reveals different strategies and challenges. Job displacement concerns, especially for professional drivers, fuel public skepticism (AV_E1). Shared mobility and freight transport have become key focus areas due to the high costs and limited use cases of private AVs. Long-haul freight automation addresses labor shortages and efficiency goals, with significant advancements expected by

2027, though private vehicles face slower adoption due to practical constraints (AV_E1). At the same time, German OEMs are investing at varying levels, with some constrained by stiff organizational structures, while agile tech companies like Tesla are driving innovation and scalability (AV_E2, AV_E9). Future visions for autonomous systems emphasize scalability, practicality, and societal benefits, though Level 5 autonomy remains a distant goal due to significant technological and regulatory challenges (AV_E2). Current efforts focus on advancing Level 4 systems in controlled environments, such as robo-taxis in urban areas, to address specific use cases (AV_E2). Scalability and cost reductions are key, with AV_E5 highlighting the need for economic viability and AV_E3 stressing that public trust as "wide-scale adoption in dense urban areas will need more time until the urban technology matures and public trust builds."

Based on the conducted expert interviews, significant progress has been made in Level 4 autonomous systems. However, challenges remain in terms of scalability, reliability in extreme conditions and handling of edge cases. Experts emphasize the importance of data collection, sensor integration and system redundancy for safety and robustness. Adoption is hampered by gaps in rural infrastructure and fragmented regulation. Public perception remains mixed, with security concerns and trust building critical, particularly in Germany. A coherent regulatory framework and harmonized international standards are essential for global scaling and innovation in autonomous technologies.

4.4.2 Survey Results

Although this part of the thesis primarily focuses on Germany, as previously mentioned, the survey on public perception was collaboratively designed to encompass all three industries. In particular, a significant proportion of 149 out of 215 respondents (69%) were from Germany.

This ensures that the survey results are sufficiently representative to support the analysis and to contrast the findings with the expert interviews conducted.

The survey findings provide valuable insights into the public's perception of AVs, revealing both opportunities and challenges for broader acceptance. The visualization of the survey results for autonomous driving can be found in Appendix A3.2 (Chart 4 to Chart 13). Familiarity with AVs is moderate, with 44% of respondents familiar with the concept, while 37% are "rather not familiar" or "not familiar at all". A significant positive correlation ($r = 0.412$; $p\text{-value} < .001$) between familiarity and willingness to take a ride in a fully autonomous car highlights the importance of awareness in influencing acceptance. Similarly, the survey shows a weaker but notable correlation ($r = 0.207$; $p\text{-value} = 0.002$) between tech-savviness and willingness to use an AV, suggesting that technological confidence also plays a role. When asked about the willingness, 62% of respondents selected that they are willing, with safety and trust emerging as critical factors. Concerns about safety were rated "very important" by 62% and "rather important" by 29%, making it the largest barrier to acceptance. Trust in autonomous technology also plays a critical role, with 68% considering it as important. These findings align with expert insights, which emphasize the significant need for transparency, reliable performance, and robust safety guarantees to foster public confidence. For participants reluctant to ride in an AV, the guarantee of safety features is the most compelling motivator (97%) to change their mind, followed by prior positive experiences and recommendations from trusted sources. Pilot projects and test rides were identified as effective strategies in convincing people to take a ride in AVs in the future. Among participants willing to ride in an AV, multiple layers of safety systems (99%), trust in advanced technology (90%), and compliance with legal and ethical standards (91%) remain top priorities, reinforcing the importance of safety and reliability. Benefits of AVs, such as convenience (73% of willing participants and 67% of unwilling participants rated it important) and cost savings, are valued by both groups. However, experiential aspects like enjoyment of travel are more influential for participants willing to ride in AVs. Social status remains the least important factor, dismissed as “not important at all” by 40% of willing participants and 46% of reluctant participants. Preferences for travel scenarios show that both groups favor predictable environments with highways and inner-city travel as the top choices. Rural roads remain a shared concern, with only 19% of willing and 22% of unwilling participants preferring them, underscoring trust and reliability challenges in less predictable environments. In summary, the survey findings underscore the critical need to address public concerns about safety and trust while enhancing familiarity through communication and pilot programs. These efforts, combined with industry advancements, are essential for fostering broader acceptance of AVs.

4.4.3 Industry Conclusion

The findings suggest that Germany has made significant progress in AV technology, for example in Level 3 systems already implemented in premium vehicles. These are already working under certain conditions and represent a significant step towards practical deployment. However, wider adoption of Level 4 technology faces challenges as it currently requires ideal conditions and is limited to geofenced areas, similar to projects in China and the US, as mentioned in the interviews. In addition, experts believe that achieving Level 5 automation is currently unrealistic. Germany faces specific hurdles with Level 4 systems, including difficulties in managing edge cases and a lack of robust data to handle complex scenarios such as unpredictable pedestrian behavior or adverse weather. Financial constraints in Germany further complicate these technological challenges, especially when compared to the more substantial resources available to technology companies in the US and China. The survey conducted underlines public concerns about safety and trust in technology, which experts also highlight as critical to adoption. Successful pilot projects and clear communication are essential to build trust and familiarity with autonomous driving. As indicated by a significant correlation between familiarity with AVs and willingness to engage, suggesting that positive experiences could boost public acceptance.

In conclusion, while Level 4 autonomous systems are still aiming for wider deployment, targeted applications in public transport and robo-taxi services are expected to help Germany make progress. These initiatives allow for controlled testing and gradual public acceptance through real-world experience. Addressing software limitations, overcoming financial and regulatory barriers, and tackling edge cases through improved data collection and advanced simulation technologies are crucial to advancing autonomous driving technology. Furthermore, aligning infrastructure developments with these efforts will ensure smooth integration. By focusing on these priorities and fostering collaboration between policymakers and industry, Germany can advance its position and become more competitive in the global AV landscape, effectively competing with countries such as the US and China. Cross Industry Discussion

5.1 Technological Constraints

The gap between the technological potential and the operational readiness for large-scale deployment presents a common challenge across all three industries. While highly automated and autonomous systems in each sector are already technologically advanced, their full implementation in real-world, dynamic environments remains a work in progress. The technology is still limited to controlled environments in which it operates under noncomplex conditions. Some experts claim that in these sterile environments, the technology is already sufficient for operation. This reflects a broader trend across all industries in which the technology is capable of handling basic tasks but struggles to manage edge cases –

unpredictable scenarios that require the system to adapt quickly and safely. These solutions, as initially stated in chapter 2.1, thus do not yet meet the core requirements of an autonomous system, as defined by McClean (2021), which include the ability to adapt to dynamic environments and effectively respond to unexpected hazards.

There are currently no adequate solutions that can handle situations like single-pilot incapacitation, bird strikes or unexpected weather conditions. In the case of SiPO, edge cases such as pilot incapacitation in form of medical emergencies are particularly troubling due to the absence of a copilot who could take over. This necessitates not only advanced automation systems capable of assuming complete control but also reliable mechanisms for ground intervention or support. For AVs, scenarios like navigating through sudden, severe weather changes or handling unexpected pedestrian actions remain major hurdles. These require improvements in sensor technology and AI to enhance perception and decision-making under varied and unpredictable conditions. Meanwhile, autonomous UAM poses critical risks not only from unplanned airspace incursions, but also from technical system failures, as highlighted by UAM_E2. Addressing these challenges across these sectors requires advancements in ML, enhanced data collection for training algorithms, and robust testing in diverse, real-world scenarios.

Interestingly, some experts have, however, hinted that increased automation might actually reduce safety in certain cases. SiPO_E3 mentioned that “there is a school of thought that says that two of the major accidents that have occurred (737 MAX) have been due to more automation.” UAM_E1 furthermore mentions that simply “removing human involvement would eliminate 80% of accidents” is too biased as “there are countless instances where human intervention prevented technical issues from escalating into accidents.” In this context, SiPO_E1 indicates that sometimes more automation means to accept a lower safety standard.

It is incredibly hard or close to impossible to improve the commercial aviation safety record with improved automation, simply because the current safety record with dual-pilot operations is so exceptional (SiPO_E3). For autonomous driving, experts generally start from the premise that it is safer than the average human driver. However, AV_E1 highlights the importance of being transparent about the limitations of safety: "There is an unrealistic expectation from the public that autonomous systems will deliver a perfect safety record." While the major goal is to improve safety, and although incidents can be reduced, it is crucial to communicate that safety cannot be guaranteed in every scenario and accidents may still occur. This underscores the need for ongoing improvements in technology and safety measures, as well as the necessity for clear communication with the public about what autonomous driving can realistically achieve in terms of safety.

5.2 Commercial Viability

Although the deployment of autonomous UAM requires large-scale infrastructure investments, and the integration into existing airspace is a major challenge, experts are confident that there will be autonomous passenger drones in the future. The concept is being pursued by many start-ups and is increasingly being supported by investors and governments. However, the German startup Lilium lately had to declare bankruptcy due to lack of funding from investors and especially the German government (Browne 2024). This case shows that young UAM companies are still heavily dependent on investors and that even the development of non-autonomous passenger drones carries an extremely high risk. Despite the experts' certainty that these will sooner or later become established, there is no guarantee of success for these companies. The same need for financial support also applies to AVs. Experts foresee implementation starting with robo-taxis and public transportation, followed by eventual integration into the premium segment on the roads in the future. This will require significant investments from OEMs to address current technical challenges.

SiPO, on the other hand, is less popular and is only being pursued by a few companies and research facilities. Among the general public, the concept is being portrayed very negatively, especially by pilot associations. Experts are unsure whether the concept will ever be adopted, not only because of safety concerns but also because of economic viability. Economic benefits of SiPOs may not be given, since commercial aviation is profitable even with two pilots, but a lot of investment is still needed for successful deployment. SiPO are considered by many experts and pilots to be an unsafe concept that can only meet the safety standards of dual-pilot operations, if at all but not exceed them. Therefore, commercialization and subsequently cost savings are likely to play a more important role for current advocates and supporters of the concept than safety improvements. Experts, on the other hand, doubt the profitability of the concept due to the high research and investment costs and financial risks, which reveals an interesting contradiction between some experts and industry advocates.

For autonomous UAM, the concept of autonomous flight is inevitable to guarantee economic efficiency for the UAM industry, since profitability is based on scalability and, due to the low number of passengers per eVTOL, this can only be achieved by flying without a pilot. As UAM_E6 states, “if you’re aiming for mass deployment […], you need fully automated systems.” In this context, UAM_E1 raised an interesting aspect of Volocopter’s current business model, which focuses on piloted eVTOLs. Apparently, the start-up's business plan assumes more daily flight hours than a Boeing 737 – “the most proven design in aerospace” (UAM_E1). According to the expert, these start-ups believe that they will one day eventually surpass the efficiency of this optimized and well-established aircraft. However, as the conducted interviews suggest, this scenario is far from possible at this stage. Achieving such mass deployment would require advanced automation technologies across the entire flight procedure and ATM – a milestone that is still years away.

Nevertheless, the economic feasibility of companies in the UAM sector is further challenged by the high costs associated with current technology and operations. According to UAM_E3, this particularly applies to two-seated vehicles such as the VoloCity (eVTOL developed by Volocopter designed for short urban flights of maximum 35km), as the "pilot costs more than anyone would ever pay for a ticket." By removing the pilot and thus adding an additional passenger seat, a higher degree of automation is expected to lead to more affordable UAM ticket prices in the future. This is in line with the findings of Schweiger and Preis (2022) presented in the literature review. UAM_E2, however, highlights cost-related challenges in adopting automation technologies, calling for more cost-effective solutions in order to enable mass affordability. This aligns with findings from the automotive industry, as the high costs of high-precision LIDAR sensors and advanced technical equipment make the technology for autonomous vehicles too expensive for the average consumer. As noted by industry experts, "individual components like sensors and computing systems are advanced, [but] their cost remains a barrier to commercialization, especially for private vehicles" (AV_E1). For this reason, it is more practical to initially adopt the technology in shared mobility services or public transportation, where it can achieve faster cost amortization. Until costs decrease, autonomous technology will primarily be seen in the premium segment, such as in vehicles like the Mercedes S-Class (AV_E3). Furthermore, scaling the technology to become commercially viable presents challenges. However, in the longer term, economies of scale are expected to make this technology more affordable and accessible to broader markets.

5.3 Familiarity and Social Acceptance

As illustrated in Chart 1, when comparing the survey results across all three industries collectively, AVs receive the highest level of public trust, with a significant proportion of respondents indicating they are “rather willing” or “very willing” to use this mode. In contrast, SiPO shows the lowest levels of willingness, diverging from the views of some experts who argued that public perception would not be a significant barrier for this concept. For autonomous UAM, despite more participants expressing reluctance to use this mobility service, the results reveal a more balanced distribution along the scale compared to the other two transport solutions. These findings highlight both the potential and existing barriers to public acceptance of this highly emerging mode of transport. To leverage the novelty of autonomous UAM, stakeholders should therefore focus on proactively communicating safety, reliability, and potential benefits. According to the experts, early public engagement is essential to build trust and reduce skepticism.

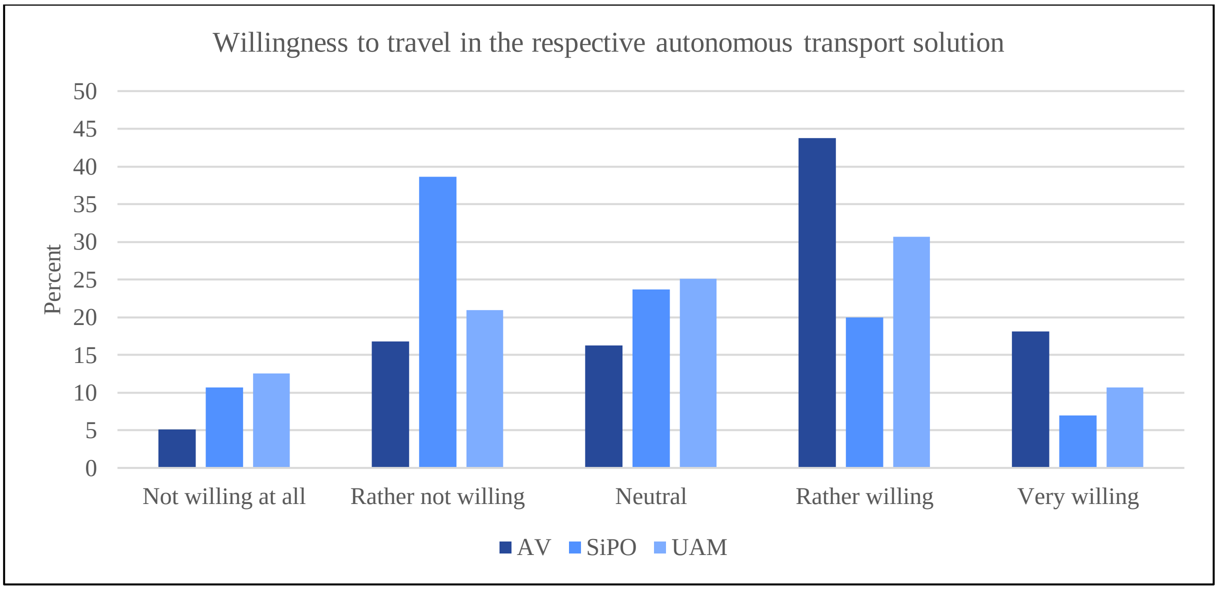

Chart 1: Comparison between the willingness to travel in the respective transport solution between autonomous AV, SiPO, and autonomous UAM

Furthermore, the comparison of public perception reveals that 53% of participants expressed the highest trust in autonomous driving compared to the other two modes of transport (Appendix A3.2 Chart 32). This finding is based on a direct question requiring respondents to select the transport mode they trust the most. In contrast to the questions assessing people's willingness to use each mode of transport (Chart 1), this question specifically focused on identifying the transport solution participants felt was the most trustworthy overall. This result is likely attributed to the greater familiarity with autonomous driving, as 44% of participants reported being at least "rather familiar" with this mode, while familiarity with autonomous UAM (21%) and SiPO (9%) is much lower. A significant correlation between familiarity and willingness to ride in the respective industries suggests that public discussions that increase awareness could positively impact the public's willingness to use autonomous or highly automated modes of transportation. This also reconciles AV_E2's opinion, that the "acceptance among the population will depend heavily on exposure and familiarity." Experts across the industries agree that proactive communication and providing reliable information about the technology and safety features positively influences people's perception. Moreover, experts and the survey results reveal that showcasing successful track records and prior positive experiences are important factors shaping attitudes towards such technologies. Despite varying levels of familiarity and differences in participants' willingness to use the three modes of transport, safety remains the primary concern for the majority. In this context, the findings regarding the most trusted mode of transport are particularly interesting. Commercial flying is the safest form of transport, measured by travelled distance, while the car is the most dangerous one (Handelsblatt 2013). However, most participants chose autonomous driving as the most trustworthy mode of transport. This discrepancy between perceived and actual safety underscores the complexity of public trust in autonomous technologies and the importance of familiarity in order to build trust.

Public perception was used as a readiness indicator as the public holds a certain amount of power in regard to the establishment of innovations. Expert claims and the survey show that measures are necessary to familiarize the public with autonomous mobility concepts in order to make them a realistic option for commercial and scaled use. In order to increase the probability and speed of successful implementation, stakeholders, who are currently still largely the developers of the respective mobility solutions, could address the public more and facilitate an exchange between regulatory authorities and the public. The survey shows that for more than 90% of all participants willing to travel with the respective transport solution, compliance with regulations was "rather important" or "very important", making it the second most important factor after multiple layers of safety systems for autonomous driving, SiPO and autonomous UAM (Chart 2).

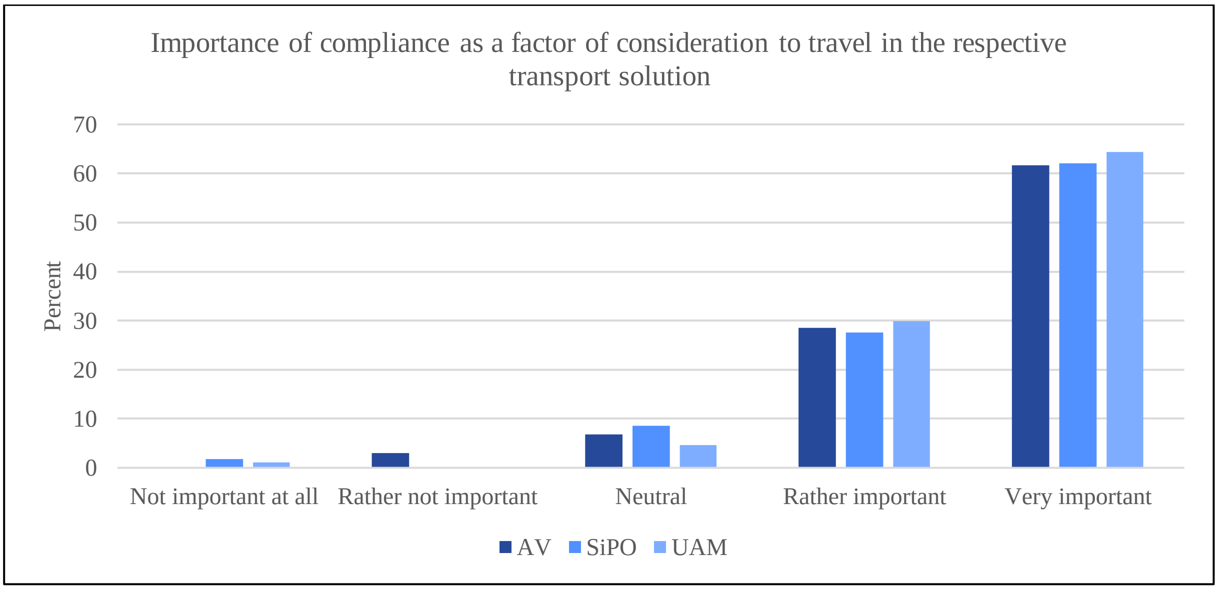

Chart 2:Comparison between the importance of compliance as a factor of consideration to travel in the respective transport solution between autonomous AV, SiPO, and autonomous UAM

This shows the public's confidence in regulators, who, apart from certifications, can contribute to the actual introduction of autonomous mobility solutions by strengthening public trust, similar to what Blind (2011) suggested. Once these autonomous solutions can prove an improved safety record compared to non-autonomous mobility, regulators and governments will have a greater interest in promoting autonomous transport to the public.

5.4 Regulatory Complexities

The development of regulatory frameworks and certification processes varies greatly between the analyzed industries. With the AFGBV Level 4 Act for autonomous driving already in place, and experts not seeing regulation as the main barrier, the automotive industry is the most advanced one in terms of deployment. AV_E8 adds that “Level 4 automation may become viable for limited use cases, robot-taxi fleets, by 2030.” However, challenges remain in the fragmented landscape within Germany but also on an EU-level lacking unified regulations beyond national borders, according to AV_E1 and AV_E3. The groundwork has been established, but “overcoming challenges in the regulatory and approval process […] is a critical milestone” (AV_E1), particularly in ethical considerations in regard to liability, according to AV_E7 and AV_E8.

Nonetheless, regulations for SiPO and autonomous UAM pose a much greater challenge, as there are no frameworks that can cover certification for highly automated or autonomous tasks. Current regulations for CAT are built to control dual-pilot operations, missing a structure to “address accountability and liability in a SiPO environment” (UAM_E4). Simultaneously, eVTOLs represent a completely new type of vehicle in themselves. UAM_E3 mentions that “single-pilot operation is already a big innovation [and] milestone,” indicating that certifying SiPO is extremely challenging and autonomous flight is a step further than that. Particularly in light of the previously discussed unpredictable scenarios, these regulatory frameworks "need to address all the corner cases" (UAM_E7) in a manner that ensures safety to both civil aviation authorities and the broader public. Moreover, with the regulatory environment being dominated by two major authorities, the FAA and EASA, varying approaches could complicate global standardization. Interestingly, while the certification of SiPO seems closer from EASA's standpoint and the FAA being more reluctant, the UAM experts see the US as being further ahead in the implementation, with lower safety standards. Therefore, future and adequate regulations will first have to address piloted passenger drones before gradually covering full autonomy, which experts do not expect before 2040. Similarly, for the use of SiPO, experts could imagine partial deployment in the form of eMCO and implementation in the cargo sector within the next 10-15 years.

5.5 Cross-Industry Collaboration and Knowledge Transfer

The insights from experts across all three industries also reveal promising opportunities for collaboration and knowledge transfer. As UAM_E1, UAM_E5 and SiPO_E4 point out, cross-industry collaboration can play a crucial role in improving public acceptance, raising awareness for the safety of autonomous technologies. In this context, UAM_E1 draws parallels to the successful introduction of autonomous metros, demonstrating how effective communication strategies can help in fostering trust. To gradually introduce these modes of transport and slowly build public acceptance, mobility providers could develop "integrated transportation packages" as suggested by AV_E2, that combine AVs and aviation to provide "seamless customer experiences." According to AV_E7, airlines could partner with robo-taxi providers to offer smooth "door-to-door solutions" for passengers, effectively bridging the gap between airports/vertiports and their final destinations. This perspective aligns with UAM_E6, who notes that current UAM concepts still depend on first- and last-mile connectivity to enable passengers' access eVTOLs.

As previously mentioned, UAM players such as Wisk are focusing purely on the development of autonomous technologies. Rather than launching autonomous air taxis in the near future, the company's goal is to introduce a deep and fully developed autonomous system when the time is right. As Wisk is funded by Boeing, UAM_E6 interestingly mentions that Boeing's primary motivation behind this financial decision is "less about launching air taxis [themselves] and more about using these technologies in commercial aviation." This example highlights the potential for cross-industry knowledge transfer, where advancements in one area can influence broader aviation applications. Moreover, SiPO_E3 and SiPO_E5 also mention that there are lessons to be learned from autonomous cars, especially mentioning Waymo and their control centers. Conversely, AV_E5, AV_E8, and AV_E11 argue that the aviation industry offers valuable insights, particularly in areas like safety, redundancy, and human-machine interaction – principles already adopted in automotive. AV_E6 further adds aviation's long-standing use of systems like autopilot and simulation-based testing. On the other hand, the SiPO experts agree that learnings from the automotive industry are possible but limited, as aviation is more complex and has unique safety standards. SiPO_E3 adds to this that "[autonomous cars] can always just pull over if there's a problem."

Furthermore, sensor technology is considered a promising field, with several experts highlighting advancements in the automotive industry. UAM_5, for example, notes that advancements in autonomous driving "could make sensors cheaper through economies of scale," thus benefiting the aviation industry. Similarly, communication systems and 5G technologies developed for AVs are seen as valuable for UAM, although UAM_E3 points out that the faster movement through airspace presents challenges for directly transferring such technologies.

As a result, collaboration with the telecommunications industry emerges as a key focus, with experts from both the automotive and UAM sectors emphasizing the crucial role of mobile service providers and tech companies in driving these advancements. In addition to partnerships with external industries, collaborations between the automotive and UAM sectors themselves present valuable opportunities for technological progress. UAM_E9 specifically highlights the potential of engineering services for cross-industry collaboration. In this context, he points to already existing partnerships, such as between Geely and Volocopter, Mercedes-Benz and Volocopter, as well as Hyundai and Supernal. According to the expert, “these partnerships are becoming the norm, demonstrating how companies from diverse industries are working together to advance automation technologies and scale solutions” (UAM_E9).

Nonetheless, distinct industry characteristics may also hinder potential collaboration. For instance, the automotive industry, optimized for large-scale production, operates with different quality and safety standards compared to aviation, which faces higher regulatory hurdles and smaller operational scales. UAM_E8 further notes that while smaller systems like eVTOLs are less constrained by the strict requirements of traditional aviation, they offer better opportunities for innovation and experimentation. While UAM_E3, for instance, advocates for shared systems within aviation since aircrafts and eVTOLs “are flying in the same airspace,” UAM_E7 holds a more critical position, revealing the different views on collaboration potential across industries. He mentions that despite the apparent overlaps, the “underlying business contexts are vastly different.” AV_E2 and AV_E4 also emphasize the differing operational contexts, which limit the direct transfer of solutions across industries. This is echoed by

UAM_E5, who emphasizes that "the market dynamics and passenger capacities" of traditional aircrafts and eVTOLs set them apart. UAM_E8 concludes that despite the overlap in technologies, significant differences "often prevent seamless collaboration."

6. Limitations and Future Research

This paper offers a first step to combine the views of industry professionals and potential passengers on automation technologies in three different transportation sectors, significantly influencing current and future mobility. However, this thesis faces some limitations.

Findings of this work are constrained by the availability of appropriate resources. First, even though several experts from different stakeholders of each industry were interviewed, a certain bias must be expected. Simultaneously, their opinions might not reflect the industry's overall perspective. Experts employed at companies specifically focused on the development of single-pilot operated aircraft and autonomous passenger drones, as well as some OEMs focused on autonomous driving, unfortunately refused to participate in interviews, citing confidentiality guidelines as the reason for their rejection. Additionally, some experts, particularly from the aviation industry, have only agreed to give interviews in writing, which has prevented follow-up questions and impacted the interviews' thematic depth. Since SiPO is a less popular topic, the availability of qualified interview partners was limited. Furthermore, the analysis of autonomous driving was focused on Germany, limiting it to a single country with only minor comparisons to other global players in the automotive industry, such as China and the US. This geographic focus may restrict the generalizability of the findings across different regulatory and market contexts. Additionally, the survey does not represent the general public, as the sample is mainly composed of young and German participants. Moreover, due to the questionnaire's design, the respondents' choices might have been influenced by framing effects caused by predetermined answer options and the usage of a Likert scale. Above all, the page limitations prevented a more detailed examination for all three industries.

For future research, it would be advantageous to engage a more diverse range of experts, specifically those with deep expertise in the relevant technologies, in addition to insights from regulatory and governmental perspectives. This approach would ensure a more comprehensive understanding of the subject matter. Furthermore, we recommend a survey with a more diverse group of participants, as the composition of mainly German participants led to an unintentional representation of the German population. Additionally, for further research with a broader scope, a more in-depth analysis should be conducted. Finally, as this paper only provides a current snapshot of expert perspectives and public perception, both evolving as rapidly as the technology itself, this area is undoubtedly worth additional exploration in future studies. To further assess the future of mobility and the increasing role of automation technologies, analyzing and drawing comparisons with other transportation industries could provide additional insights and areas for further examination.

7. Conclusion

Automation in mobility, as emphasized at the beginning of this paper, is often driven by the aim to reduce human error and enhance safety across all sectors. Of course, these are important aspects that are indispensable for any mode of transportation. Nevertheless, the interviews with various experts show that other, particularly commercial aspects, such as cost savings or the potential for future scalability, also play an important role in the development of automated technologies. The realization of advanced automation and autonomy varies significantly across AVs, SiPO and autonomous UAM, reflecting their differing stages of maturity.

While all three industries showcase advanced technological capabilities, the gap between these advancements and full operational readiness remains a central challenge. Considering the readiness factors described in chapter 2.2, autonomous driving is the most advanced concept, favored by established regulatory frameworks and higher levels of public familiarity and trust. Conversely, the limited exposure and novelty of SiPO and autonomous UAM are reflected in the population's lack of trust and hesitation. Familiarity with the technology positively correlates with the peoples' willingness to use them. A further challenge for SiPO and autonomous UAM is the difficulty of adapting the respective regulations, which requires the development of entirely new frameworks. Although the technological status of SiPO is arguably more advanced than autonomous UAM, partly because aviation has been using autonomous systems in the cockpit for many years, the introduction of autonomous air taxis seems more realistic for economic reasons. This may be due to the fact that aviation is already profitable with two-pilot operations, whereas UAM can only become profitable with full autonomy. This could remove the financial incentive to pursue SiPO. At the same time, cross-industry collaboration can provide valuable opportunities for further advancements in technology, public acceptance and cost-effectiveness. Differences in operational contexts, however, may limit the direct transfer of knowledge and solutions between industries that may seem obvious.

As outlined in the introduction, these automation technologies across all three industries are sufficiently advanced to be assessed but still far enough away to be influenced by uncertainty. This analysis confirms that while their adoption is within a foreseeable timeframe, realizing their full potential will require overcoming technical limitations, refining regulatory frameworks on a global scale, and convincing the public of the benefits and safety of automated and autonomous mobility. Looking to the future, experts see the potential to develop integrated mobility concepts that combine UAM, SiPO and AVs to create a seamless and efficient transport ecosystem.

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Appendices

A.1 List of Abbreviations

ADAS	Advanced Driver Assistance System
ALPA	Air Line Pilots Association
ATM	Air Traffic Management
AI	Artificial Intelligence
AV	Autonomous Vehicles
CAT	Commercial Air Transport
CNS	Communication, Navigation, and Surveillance
EASA	European Union Aviation Safety Agency
eMCO	Extended Minimum Crew Operations
EV	Electric Vehicle
eVTOL	Electric Vertical Take-Off and Landing Aircraft
FAA	Federal Aviation Administration
IATA	International Air Transport Association
LIDAR	Light Detection and Ranging
ML	Machine Learning
R&D	Research and Development
SiPO	Single-Pilot Operations
UAM	Urban Air Mobility
UNECE	United Nations Economic Commission for Europe
V2V	Vehicle-to-Vehicle

A.2 Figures

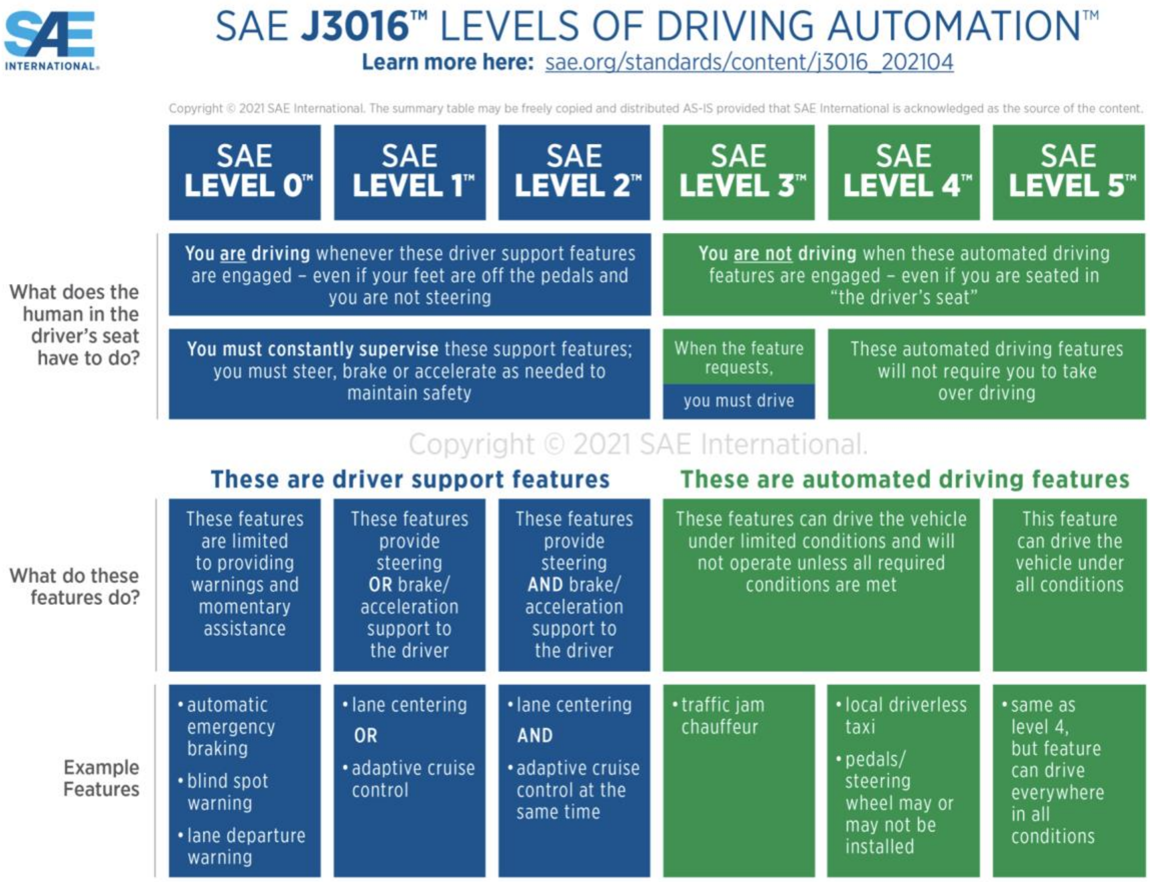


Figure 1: SAE J3016 Levels of driving automation (Source: SAE International 2021)

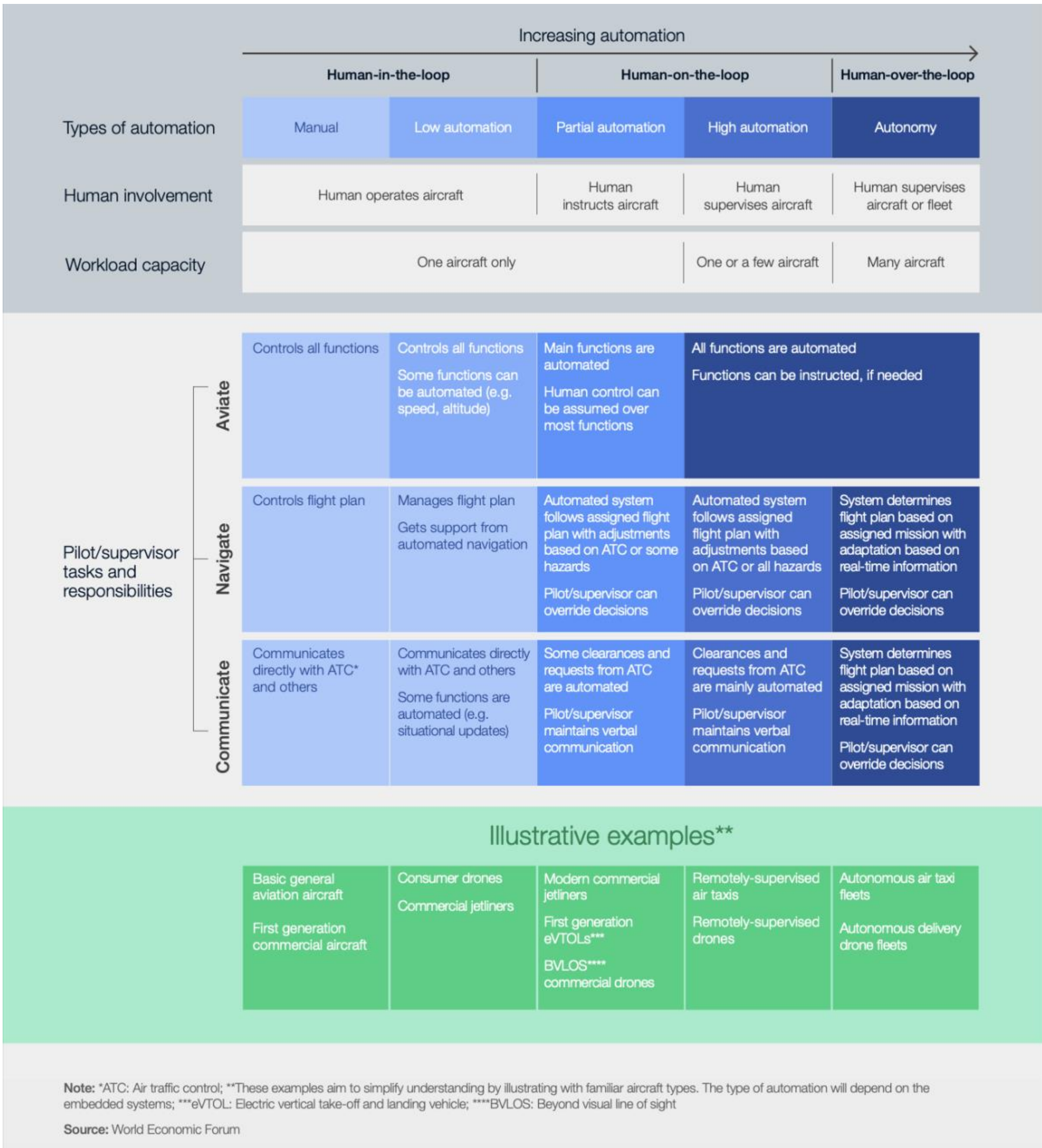


Figure 2: Automation taxonomy for aviation (Source: World Economic Forum 2024)

A.3 Expert Interview Guide

INTRODUCTION

Thank you for participating in this interview. Your insights will be highly valuable to my research. My name is [name] and I am a Master's student in [degree] at Nova School of Business and Economics in Lisbon. We are currently writing our thesis about industry readiness in autonomous mobility solutions, comparing insights from industry professionals with the public perception across the automotive, aviation and UAM industry. This interview will last approximately 45 mins. We will start with a brief introduction to your background before we move to the discussion of the topic of automation in [industry]. In case of any question, do not hesitate to raise them throughout the session. Would you mind if I record this interview and if I use your real name in my thesis?

BACKGROUND

Could you please introduce yourself by describing your current position and responsibility?

Could you please elaborate on other relevant positions you held in the industry?

INDUSTRY READINESS & TECHNOLOGY ADVANCES

How ready is the technology behind (autonomous driving / SiPO / autonomous passenger drones) for operational/commercial use?

What are the most significant challenges your industry faces in adopting automation technologies (autonomous driving / SiPO / autonomous passenger drones)?

IMPACT ON HUMAN ROLES & EMPLOYMENT

What new skills or competencies will be required for the future workforce with the increase in automation levels?

REGULATORY FRAMEWORK & SAFETY

What changes or adaptations do you believe are necessary in the regulatory framework to support (autonomous driving / SiPO / autonomous passenger drones)?

What is your prediction if and when regulations will be relaxed?

Are there notable differences in how automation is regulated across different regions or countries?

How do these variations impact the industry's global strategies and readiness? / Do you think (autonomous driving / SiPO / autonomous passenger drones) will be implemented first in a certain country/region?

What are the primary safety concerns from an operational standpoint? How will safety be enabled with increased automation?

PUBLIC PERCEPTION & TRUST IN AUTOMATION

How would you describe the current public perception and trust in automation technologies within your industry?

In your opinion, what are the most important factors for acceptance among the population?

How are they being addressed?

FUTURE OUTLOOK & STRATEGIC VISION

What do you see as the main milestones for automation in your industry in the near future?

What do you believe are the key success factors for widespread implementation of automation in your industry?

COMPARATIVE ANALYSIS ACROSS INDUSTRIES

Are there collaborative opportunities with other industries that could accelerate or hinder automation implementation in your field?

WRAP-UP

We have now reached the end of the interview. I would like to thank you again for your participation. Do you any other questions or comments that you would like to share?

A.3.1 Expert Interview Analysis after Mayring

A.3.1.1 Autonomous Driving Experts

Expert Number	Interview Language	Paraphrase	Generalization	Category	Code
AV_E1	German	"While individual components like sensors and computing systems are advanced, their cost remains a barrier to commercialization, especially for private vehicles."	High costs of advanced components hinder the commercialization of autonomous systems, particularly for private vehicle use.	Industry Readiness & Technology Advances	Cost Barriers
AV_E1	German	"Redundancy in sensory systems and computational frameworks enhances safety, but also adds complexity and cost."	Redundant sensory and computational systems improve safety but increase complexity and costs, posing challenges to scalability.	Industry Readiness & Technology Advances	Cost Barriers
AV_E1	German	"Accessibility and affordability are also paramount. Even if the technology is advanced and functional, it will fail to gain traction if it is perceived as a luxury."	Accessibility and affordability are key to ensuring broad adoption, as expensive technologies risk being viewed as exclusive.	Future Outlook & Strategic Vision	Cost Barriers
AV_E2	German	"Sensor technology like lidar remains expensive, and building the infrastructure to support autonomous vehicles requires significant investment."	High costs of lidar sensors and infrastructure development present economic barriers to adopting autonomous systems.	Future Outlook & Strategic Vision	Cost Barriers
AV_E2	German	"Traditional OEMs often struggle with securing the financial resources needed to compete with well-funded tech companies."	Financial constraints make it difficult for traditional OEMs to compete with tech giants in developing autonomous technologies.	Future Outlook & Strategic Vision	Cost Barriers
AV_E3	English	"The economic situation in the automotive industry, especially in Germany, limits resources for research and development in autonomous and electric vehicles."	Financial pressures in the automotive industry, particularly in Germany, restrict investment in autonomous and electric vehicle R&D.	Future Outlook & Strategic Vision	Cost Barriers
AV_E3	English	"Companies face difficulties sustaining the long-term investments needed to advance automation technologies due to economic constraints."	Economic constraints in the industry challenge the sustainability of long-term investments in automation development.	Future Outlook & Strategic Vision	Cost Barriers
AV_E3	English	"If the technology is too expensive, it will only be available to a small group of people. Affordable costs will encourage more people to try it, even if they're initially unsure."	Cost is a critical factor; affordable pricing is necessary to broaden accessibility and drive adoption of autonomous systems.	Future Outlook & Strategic Vision	Cost Barriers
AV_E4	German	"Current autonomous driving systems rely on expensive components, such as sensors, actuators, and perception systems, which need cost reductions for broader commercial viability."	The high cost of autonomous vehicle components, like sensors and actuators, limits commercial scalability and requires cost reductions through economies of scale.	Future Outlook & Strategic Vision	Cost Barriers
AV_E4	German	"Cost is another significant factor for acceptance. If autonomous vehicles are seen as too expensive, they will	Cost accessibility is a critical factor for widespread public	Public Perception & Trust in Automation	Cost Barriers

		remain out of reach for most people, limiting adoption."	adoption of autonomous vehicles.		
AV_E5	German	"The hardware and software required to support autonomous functions are inherently expensive, adding to the financial burden for development and deployment."	The high costs of hardware, software, and extensive testing for autonomous systems pose a significant barrier to affordability and adoption.	Future Outlook & Strategic Vision	Cost Barriers
AV_E6	German	"Right now, the technology for full autonomy, especially at Level 4, is incredibly expensive. It's much more practical for shared mobility services, like robo-taxis, where the vehicle is in constant use and the costs can be spread out."	High costs of full autonomy technology make it more viable for shared mobility services like robo-taxis rather than private ownership.	Future Outlook & Strategic Vision	Cost Barriers
AV_E7	German	"Cost is another significant factor for acceptance. If autonomous vehicles are seen as too expensive, they will remain out of reach for most people, limiting adoption."	Cost reduction is crucial to make autonomous vehicles accessible to a broader audience, beyond premium markets.	Future Outlook & Strategic Vision	Cost Barriers
AV_E8	German	"These processes take years and require billions in investment."	Validation of autonomous systems is time-intensive and requires substantial financial investment.	Industry Readiness & Technology Advances	Cost Barriers
AV_E9	German	"There's also the challenge of scaling commercially viable systems, particularly with expensive sensors and computing requirements."	Scaling autonomous systems for commercial use is hindered by high costs associated with sensors and computational resources.	Future Outlook & Strategic Vision	Cost Barriers

Reduction: Cost remains a key barrier to autonomous driving, driven by high expenses for advanced sensors, computational systems, and infrastructure. Redundancy requirements improve safety but increase complexity and costs. Economic pressures, particularly in traditional OEMs, limit investments and hinder cost reductions necessary for scaling. Affordability is critical for adoption beyond premium segments, requiring economies of scale and innovations to make autonomous systems viable for broader use. Without addressing these challenges, widespread commercialization and accessibility will remain limited.

AV_E1	German	"Building real-world datasets through large-scale deployment of autonomous systems will be essential for advancing safety and reliability."	Real-world data collection through large-scale deployments is crucial for improving safety and reliability of autonomous systems.	Industry Readiness & Technology Advances	Data Collection
AV_E3	English	"The quality and diversity of driving data remain challenges, as routine scenarios dominate, while rare and complex cases needed for training are in short supply."	Rare and complex driving scenarios are critical for training autonomous systems but are underrepresented in existing datasets.	Industry Readiness & Technology Advances	Data Collection
AV_E3	English	"Data quality is a key concern, as available datasets often lack the variety needed to train systems for complex or unexpected scenarios."	High-quality and diverse training data is essential for enabling autonomous systems to generalize effectively to unpredictable situations.	Industry Readiness & Technology Advances	Data Collection
AV_E3	English	"Improving the quality and diversity of data used to train autonomous models is essential to prepare systems for unexpected or unusual events."	Enhancing training datasets with diverse, real-world scenarios is crucial for enabling autonomous systems to handle complex and unpredictable situations.	Industry Readiness & Technology Advances	Data Collection
AV_E4	German	"Autonomous systems need to cover millions of real-world traffic	Ensuring absolute safety in autonomous systems	Industry Readiness &	Data Collection

		scenarios to validate their reliability, requiring massive datasets and advanced self-learning algorithms."	requires extensive datasets and advanced self-learning algorithms to handle diverse real-world scenarios.	Technology Advances	
AV_E4	German	"Building and maintaining this database is a complex task that demands significant time and resources."	Developing and maintaining large, high-quality datasets is a resource-intensive challenge for validating autonomous systems.	Industry Readiness & Technology Advances	Data Collection
AV_E4	German	"There's a need for massive datasets to validate autonomous systems across millions of different driving scenarios."	Massive datasets are required to train and validate autonomous systems, ensuring they can handle diverse traffic conditions and behaviors.	Industry Readiness & Technology Advances	Data Collection
AV_E4	German	"Data collection and algorithm improvements will be critical milestones as deployed vehicles generate massive amounts of data to improve system performance."	Data-driven algorithm refinement through large-scale data collection is essential for handling complex traffic scenarios and improving system reliability.	Industry Readiness & Technology Advances	Data Collection
AV_E5	German	"The leap from Level 3 to Level 4 is not trivial. Systems must reliably handle every possible driving scenario without human oversight, requiring drastic improvements in sensors and data processing."	Advancing from Level 3 to Level 4 autonomy demands significant improvements in sensor technology and data processing to handle all scenarios reliably.	Industry Readiness & Technology Advances	Data Collection
AV_E6	German	"The milestone here is to safely expand these operational areas to include more challenging environments, such as city centers with mixed traffic and unpredictable road users like cyclists and pedestrians."	Expanding Level 4 systems to challenging environments, including city centers with mixed traffic and complex scenarios, is a critical near-term goal.	Industry Readiness & Technology Advances	Data Collection
AV_E7	German	"Safety will be enabled through several mechanisms. First, data collection and real-world testing play a critical role."	Data collection and testing in real-world environments are essential for enabling safety in autonomous systems.	Industry Readiness & Technology Advances	Data Collection
AV_E8	German	"Manufacturers need to validate and verify these systems to a level where they are demonstrably safer than human drivers, and this process requires immense amounts of data and rigorous testing."	Validation and verification processes must ensure autonomous systems surpass human safety standards, requiring extensive data and testing.	Industry Readiness & Technology Advances	Data Collection
AV_E1	German	"Achieving full commercial readiness will require more work, particularly in gathering data for edge cases and real-world scenarios."	Progress toward commercial readiness depends on improving edge case handling and real-world data collection.	Industry Readiness & Technology Advances	Data Collection
AV_E1	German	"The primary safety concerns in the context of increased automation revolve around managing edge cases and ensuring reliability in diverse and unpredictable real-world scenarios."	Managing edge cases and ensuring reliability in unpredictable scenarios are primary safety concerns for automated systems.	Regulatory Framework & Safety	Data Collection
AV_E1	German	"Rigorous testing and validation are critical for exposing autonomous vehicles to countless real-world scenarios to address edge cases."	Testing and validation processes must expose vehicles to diverse real-world scenarios to address edge cases effectively.	Regulatory Framework & Safety	Data Collection

AV_E1	German	"Technology milestones include improving sensor integration, reducing hardware costs, and refining algorithms to handle edge cases and extreme conditions."	Advances in sensor integration, hardware cost reduction, and edge-case algorithm refinement are critical technological milestones for automation.	Industry Readiness & Technology Advances	Data Collection
AV_E2	German	"From a technical standpoint, there are still issues with sensor technology and algorithmic capabilities, particularly in handling complex or edge-case scenarios."	Technical challenges like sensor reliability and handling complex scenarios remain key hurdles for autonomous driving adoption.	Industry Readiness & Technology Advances	Data Collection
AV_E3	English	"The primary safety concerns revolve around ensuring autonomous systems can handle complex and unpredictable real-world environments, particularly edge cases."	Autonomous systems must reliably manage complex and rare edge cases, such as erratic drivers or sudden obstacles, to ensure safety.	Regulatory Framework & Safety	Data Collection
AV_E4	German	"The primary safety concern is ensuring that autonomous systems can reliably handle a wide range of real-world traffic scenarios, including edge cases."	Autonomous systems must be capable of reliably managing diverse real-world scenarios, especially edge cases, to ensure safety.	Regulatory Framework & Safety	Data Collection
AV_E6	German	"First off, on the technical side, we've got what we call 'edge cases.' These are rare, unpredictable scenarios—like a pedestrian suddenly jumping into the street or something unexpected falling from a building onto the road."	Edge cases, or rare and unpredictable scenarios, present significant technical challenges that autonomous systems must address for safety and reliability.	Industry Readiness & Technology Advances	Data Collection
AV_E6	German	"Another crucial milestone will be achieving reliability and safety across all scenarios, including rare and unpredictable edge cases."	Improving reliability and safety, especially in rare and unpredictable edge cases, is essential for advancing automation.	Regulatory Framework & Safety	Data Collection
AV_E8	German	"The biggest challenge with adopting automation technologies for autonomous driving is validation and verification. This involves testing edge cases—situations like when a car turns in the rain without traffic lights—and gathering the massive amount of data needed to validate the systems."	Validation and verification of autonomous systems, particularly in rare and complex scenarios, require extensive data collection and testing.	Industry Readiness & Technology Advances	Data Collection
AV_E8	German	"The primary safety concern is ensuring that autonomous systems can handle all potential edge cases reliably—things like unexpected weather conditions, unmarked intersections, or when traffic signals fail."	Autonomous systems must reliably address edge cases, such as adverse weather, unmarked roads, and failed traffic signals, to ensure operational safety.	Regulatory Framework & Safety	Data Collection
AV_E9	German	"The key challenge is handling edge cases—the rare, unpredictable scenarios that fall outside the 'average cases' autonomous systems are trained for."	Autonomous systems face significant challenges in managing rare and unpredictable "edge cases," requiring advancements in AI and machine learning.	Industry Readiness & Technology Advances	Data Collection
AV_E9	German	"This ties into solving edge cases because these outlier scenarios—things like unpredictable pedestrian behavior or rare road conditions—are exactly what hold us back from broader deployment."	Addressing edge cases, such as rare road conditions or unpredictable behavior, is critical for enabling widespread deployment of Level 4 automation.	Industry Readiness & Technology Advances	Data Collection

Reduction: Data collection is vital for advancing autonomous systems, particularly in addressing edge cases and complex scenarios. High-quality, diverse datasets from real-world deployments and simulations are essential for enabling systems to reliably manage rare and unpredictable conditions. However, building and maintaining these datasets demands significant resources, including time, computational power, and financial investment. Expanding data repositories to reflect real-world complexities is crucial for improving system robustness, ensuring safety, and fostering public trust. Advanced data collection techniques and systematic validation remain key to achieving scalable, safe autonomous driving solutions.					
AV_E1	German	"Fundamental limitations exist, including infrastructure and environmental conditions like heavy rain, fog, and snow, which pose challenges even for human drivers."	Environmental challenges, such as adverse weather conditions, remain key obstacles for automation technology, comparable to challenges faced by human drivers.	Industry Readiness & Technology Advances	Environmental Constraints
AV_E3	English	"Autonomous vehicles rely on sensors like cameras, lidar, and radar, which can be impaired by adverse weather conditions such as heavy rain, snow, or fog."	Sensor reliability in adverse weather conditions is critical for maintaining safety in autonomous vehicles.	Industry Readiness & Technology Advances	Environmental Constraints
AV_E4	German	"Sensor performance under adverse conditions, such as fog, darkness, frost, or glare, remains a significant technical hurdle."	Improving sensor reliability under adverse conditions is a key technical challenge for autonomous systems.	Industry Readiness & Technology Advances	Environmental Constraints
AV_E4	German	"A significant challenge is the performance of sensors in difficult conditions like glare, frost, or fogged-up lenses, which can affect accuracy."	Sensor performance in adverse conditions is a critical challenge for operational safety, requiring significant technological advancements.	Industry Readiness & Technology Advances	Environmental Constraints
AV_E5	German	"The vehicle's ability to respond to unexpected situations, such as sudden weather changes or erratic behaviors from other road users, is critical."	Ensuring the ability of autonomous systems to handle unexpected and dynamic conditions is a primary safety concern.	Regulatory Framework & Safety	Environmental Constraints
AV_E5	German	"Achieving robust performance in challenging conditions, such as tunnels, rain, or heavy traffic, will be a major step forward."	Autonomous systems must demonstrate reliable performance in diverse and complex environments, including adverse conditions, to reach broader applicability.	Industry Readiness & Technology Advances	Environmental Constraints
AV_E6	German	"The current state of the technology is more about expanding the capabilities of Level 4 systems incrementally, addressing issues like sensor limitations in adverse weather, and improving safety validation in rare, complex edge cases."	Current efforts focus on improving Level 4 systems by addressing sensor limitations, adverse weather, and safety in rare edge cases.	Regulatory Framework & Safety	Environmental Constraints
AV_E6	German	"Sensors like cameras, radar, and LiDAR generally work great in good weather, but when you throw in heavy snow or rain, things get tricky. To deal with this, we need better sensor performance and redundancy—so the system can rely on multiple sensors to compensate for limitations in specific conditions."	Adverse weather conditions challenge sensor performance, necessitating advancements in sensor technology and redundancy to ensure safe operations.	Industry Readiness & Technology Advances	Environmental Constraints
AV_E9	German	"These systems tend to work best in cities with favorable weather—clear visibility and dry conditions. Introducing them to places with rain, snow, or fog complicates things further."	Environmental factors like rain, snow, and fog pose significant challenges to the operational reliability of Level 4 autonomous systems.	Industry Readiness & Technology Advances	Environmental Constraints

Reduction: Environmental constraints pose a significant challenge for autonomous systems, particularly adverse weather conditions like heavy rain, fog, snow, and glare, which affect sensor reliability and performance. These factors necessitate advancements in sensor technologies, redundancy systems, and operational adaptability to ensure safety and functionality. Current efforts focus on enhancing Level 4 system capabilities to handle complex and dynamic environments while addressing these constraints incrementally. Overcoming environmental limitations is essential for expanding operational domains and achieving broader applicability for autonomous driving technologies.

AV_E1	German	"Regulatory challenges present another critical hurdle. The fragmented regulatory landscape, especially in Germany, slows progress."	Fragmented and inconsistent regulations, both within Germany and internationally, slow down the development and deployment of autonomous systems.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E1	German	"The fragmented nature of the regulatory process creates complexity because it requires agreement among the 16 federal states."	Fragmented state-level regulations in Germany create inconsistencies and inefficiencies in the approval process for autonomous driving operations.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E1	German	"At the European level, harmonization is another critical need. Currently, there is no uniform framework across the EU."	Lack of regulatory harmonization at the European level complicates scaling and cross-border deployment of autonomous vehicles.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E1	German	"International regulations, such as those under UNECE in Geneva, are not expected until 2026."	Global regulatory alignment is lagging, with international frameworks for autonomous vehicles not expected until 2026.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E1	German	"There is a restriction on small-series production in Germany—only 250 units per year per type nationally and 1,500 per type under European regulations."	Small-series production limits in Germany and Europe hinder scalability and commercialization for emerging players in the autonomous vehicle industry.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E3	English	"Standardized regulations across regions are critical, as fragmented rules in Europe create delays and inefficiencies."	Harmonized regulations are necessary to streamline testing and deployment of autonomous vehicles across borders.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E3	English	"The fragmented regulatory landscape within the EU adds complexity, as countries have their own laws and processes for testing and approval."	Fragmented regulations across EU countries create complexity and inefficiencies in the deployment of autonomous technologies.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E4	German	"There needs to be a unified set of regulations, particularly within regions like the EU, to provide manufacturers with stable guidelines and planning security."	Unified regulations and standards, especially in the EU, are critical for streamlining development and providing stability for manufacturers.	Regulatory Framework & Safety	Fragmented Regulatory Landscape
AV_E5	German	"The current regulations are often fragmented and vary significantly from one jurisdiction to another, posing a challenge for global deployment."	Fragmented regulations across jurisdictions hinder the global scalability and deployment of autonomous driving technologies.	Regulatory Framework & Safety	Fragmented Regulatory Landscape

Reduction: The fragmented regulatory landscape significantly hinders the development and deployment of autonomous vehicle technologies. In Germany, state-level inconsistencies complicate the approval process, while the absence of harmonized EU-wide

standards creates inefficiencies and delays. Globally, international regulatory alignment remains slow, with frameworks for autonomous vehicles not expected until 2026. Small-series production limits within Europe further restrict scalability and commercialization. To overcome these barriers, unified regulations and standardized processes are essential to streamline approvals, support manufacturers, and enable broader adoption across borders.					
AV_E2	German	"Level 5, which would involve full autonomy under all conditions, is still very far away from being feasible."	Achieving Level 5 autonomy remains a distant goal due to the immense challenges posed by diverse conditions and infrastructure gaps.	Industry Readiness & Technology Advances	Future Outlook
AV_E2	German	"One key milestone is achieving reliable Level 4 technology and deploying it in specific use cases, such as robotaxis in controlled urban environments."	Deploying reliable Level 4 autonomous systems in controlled environments like urban robotaxis is a critical milestone for automation.	Future Outlook & Strategic Vision	Future Outlook
AV_E2	German	"Scaling the deployment of autonomous vehicles in ways that make economic sense will require significant investment and optimization of utilization models."	Scaling autonomous systems demands investment and optimization to achieve economic sustainability.	Future Outlook & Strategic Vision	Future Outlook
AV_E2	German	"Operators will need to refine their models to ensure these systems are both efficient and financially sustainable over time."	Long-term success requires refining operational models to ensure efficiency and financial sustainability.	Future Outlook & Strategic Vision	Future Outlook
AV_E2	German	"Aligning infrastructure and regulatory frameworks to support higher levels of automation is a major milestone for the industry."	Harmonization of infrastructure and regulatory frameworks is crucial to support advanced automation levels and cross-border scalability.	Regulatory Framework & Safety	Future Outlook
AV_E3	English	"Autonomous driving can give people their time back by allowing them to focus on other things, like attending a meeting, reading a book, or relaxing."	The time-saving convenience of autonomous driving appeals to users by freeing them from the need to concentrate on driving.	Future Outlook & Strategic Vision	Future Outlook
AV_E3	English	"One key milestone is the deployment of Level 4 autonomous systems for applications like robo-taxis and shuttles in urban or semi-urban settings."	Deploying Level 4 systems in urban or semi-urban areas for specific use cases, like robo-taxis, is a significant goal for the industry.	Future Outlook & Strategic Vision	Future Outlook
AV_E3	English	"Widespread adoption in dense urban areas will take longer as the technology matures and public trust builds."	Full adoption in complex urban environments will require technological maturity and increased public trust over time.	Public Perception & Trust in Automation	Future Outlook
AV_E4	German	"The complexity of achieving full autonomy means widespread use is likely years away, depending on factors like international regulatory alignment and technological breakthroughs."	Achieving full autonomy (Level 5) is a long-term goal, reliant on regulatory alignment, technological advancements, and solving real-world challenges.	Future Outlook & Strategic Vision	Future Outlook
AV_E4	German	"Level 3 is approaching practical use, but Levels 4 and 5 will require much more time and effort before they are ready for commercial-scale deployment."	Level 3 systems are nearing commercial viability, but Levels 4 and 5 will take significant time and effort for widespread deployment.	Future Outlook & Strategic Vision	Future Outlook

AV_E4	German	"One significant milestone will be the broader commercial rollout of Level 3 autonomous systems, expanding availability and refining functionality."	The commercial expansion and refinement of Level 3 autonomous systems are key near-term goals for the industry.	Future Outlook & Strategic Vision	Future Outlook
AV_E5	German	"The technological capabilities required to enable a car to operate autonomously in all scenarios without geographical restrictions (Level 5) are still largely theoretical."	Level 5 autonomy, which requires unrestricted functionality, is still in the conceptual stage and not practically achievable yet.	Industry Readiness & Technology Advances	Future Outlook
AV_E5	German	"Scaling these technologies for wider adoption is an essential milestone. This means reducing development and production costs while maintaining safety and reliability."	Cost reduction and scalability are necessary to make autonomous technologies economically viable for both commercial and private sectors.	Future Outlook & Strategic Vision	Future Outlook
AV_E6	German	"Achieving Level 5—fully autonomous driving without any operational restrictions—is a long-term, almost utopian goal. The challenges are immense because Level 5 requires a vehicle to function seamlessly in any environment, under any conditions, and at any time."	Level 5 autonomy, requiring unrestricted operation in all conditions, remains a distant goal due to immense technical challenges and complexity.	Future Outlook & Strategic Vision	Future Outlook
AV_E6	German	"Older people or those with limited mobility could significantly benefit from autonomous systems, especially in rural areas where public transportation options are limited."	Autonomous systems are seen as particularly beneficial for individuals with limited mobility or in areas with poor public transportation options.	Public Perception & Trust in Automation	Future Outlook
AV_E6	German	"For Level 4, the focus will be on increasing the size and diversity of operational domains. Right now, Level 4 systems are restricted to specific areas, like suburbs or locations with favorable conditions."	Level 4 milestones involve expanding operational domains to include diverse and challenging areas beyond current restrictions in suburban or favorable environments.	Future Outlook & Strategic Vision	Future Outlook
AV_E7	German	"Levels 4 and 5, however, are still at the prototype stage, being tested in research environments such as universities and specialized areas like Silicon Valley."	Levels 4 and 5 autonomies remain in the prototype and testing phases, primarily in research-focused settings.	Industry Readiness & Technology Advances	Future Outlook
AV_E8	German	"In terms of timelines, I believe Level 4 solutions could start appearing on roads in a meaningful way around 2030, with limited applications such as robo-taxi fleets leading the way."	Level 4 automation may become viable for limited use cases, like robo-taxi fleets, by 2030, indicating gradual progress in adoption.	Future Outlook & Strategic Vision	Future Outlook
AV_E8	German	"In the near future, I see robo-taxi fleets and other commercial use cases leading the way as proof-of-concept projects. These will be critical for demonstrating the feasibility and safety of the technology before it reaches the mass market."	Robo-taxi fleets and commercial use cases will act as key proof-of-concept projects to demonstrate the feasibility and safety of autonomous technologies.	Future Outlook & Strategic Vision	Future Outlook
AV_E8	German	"In terms of timing, I think Level 4 systems will start appearing on roads in a more visible way around 2030, particularly in premium vehicles."	Level 4 autonomous systems are expected to appear more visibly by 2030, especially in premium vehicles, but full-scale adoption will require additional time.	Future Outlook & Strategic Vision	Future Outlook

AV_E9	German	"One is figuring out how to integrate Level 4 systems into existing infrastructure, especially in suburban and rural areas. These are the regions where public transport is less developed, so autonomous systems can really make a difference by filling that gap."	Integration of Level 4 systems into suburban and rural areas is a critical milestone, as these regions lack robust public transport and autonomous systems can help bridge the gap.	Future Outlook & Strategic Vision	Future Outlook
Reduction: Future visions for autonomous systems emphasize scaling Level 4 operations while addressing technological, regulatory, and infrastructural challenges. Near-term goals focus on advancing commercial applications, like robo-taxi fleets and limited operational domains in urban and suburban areas, demonstrating the feasibility of automation. Achieving full autonomy (Level 5) remains a distant objective, hindered by immense complexity and technical demands. Regulatory harmonization and infrastructure adaptation are essential to expand deployment areas and improve scalability. Additionally, autonomous systems are seen as particularly valuable for individuals with limited mobility and in regions with underdeveloped public transport, showcasing the potential for societal benefits alongside technological breakthroughs.					
AV_E1	German	"As vehicles increasingly rely on software-driven functionality, the focus will move away from purely mechanical components toward more complex software and data-driven operations."	Automation shifts emphasis from mechanical components to complex software and data-driven functionality in vehicles.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"The workforce will require a significant shift in skills and competencies, particularly within the automotive industry."	Automation demands a shift in workforce skills, with a greater emphasis on software expertise and system-level engineering.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"Writing software alone is no longer sufficient; it must also be made secure and attack-proof. Data security and protection will become critical areas of focus."	Data security and resilience against cyber threats are essential as vehicles become more software centric.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"System engineers will need to broaden their perspective—they will no longer just develop individual components but instead oversee how these components interact as part of a highly integrated system."	Engineers must adopt a system-level perspective, focusing on component integration within centralized architectures.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"Operational roles, such as technical supervisors managing fleets of autonomous vehicles, will need to understand the systems in depth and have a strong grasp of regulatory requirements."	Operational roles will require advanced technical understanding and familiarity with regulatory compliance to manage autonomous vehicle fleets.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"Even maintenance roles will change considerably, expanding to include diagnosing and ensuring the functionality of sophisticated automated systems."	Maintenance workers will need to diagnose and maintain complex automated systems, reflecting the shift from traditional tasks to software-centric duties.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"Routine departure checks will require knowledge of both hardware and software to guarantee that vehicles are ready to operate safely."	Maintenance routines will increasingly integrate hardware and software diagnostics to ensure operational safety.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"The industry's skill requirements will evolve from being hands-on and hardware-focused to increasingly software-driven and cognitive."	Automation will drive a transformation in workforce skills, emphasizing software-driven and cognitive abilities over traditional hardware-focused roles.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E1	German	"Interdisciplinary training will be essential to equip workers for these changes. Upskilling and continuous	Continuous learning and interdisciplinary training will be critical to equip	Impact on Human Roles & Employment	Human Factors & Skills

		learning on the job will play a key role."	workers for evolving demands in the automated industry.		
AV_E2	German	"A strong emphasis will be placed on software development and data science, including programming, machine learning, and artificial intelligence."	Future workforce needs expertise in software development, AI, and machine learning to manage autonomous systems.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E2	German	"Skills related to managing and processing large datasets will become critical, such as those needed to train AI systems using real-world data."	Data management and processing are essential for training AI systems, making data science a critical skill in automation.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E2	German	System engineering will also become increasingly important, as engineers must understand how sensors, processors, and actuators integrate into cohesive systems."	System engineering is vital to integrating components into reliable autonomous vehicle systems.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E2	German	"Cybersecurity is another area of growing relevance, as autonomous vehicles must be protected against potential data breaches and external threats."	Cybersecurity expertise is critical for safeguarding autonomous vehicles from breaches and external threats.	Industry Readiness & Technology Advances	Human Factors & Skills
AV_E2	German	"The ability to adapt and continuously learn will be critical for the future workforce, requiring regular upskilling to keep pace with technological advancements."	Lifelong learning and continuous upskilling are essential to adapt to the rapid pace of technological changes in automation.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E2	German	"Educational institutions and companies must rethink their training and development programs to prepare individuals for the evolving demands of the industry."	Training and development programs must be restructured to meet the evolving demands of the automated automotive industry.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E3	English	"A strong understanding of artificial intelligence and machine learning will be essential, even for those not directly involved in programming."	Foundational knowledge of AI and machine learning is critical for all workers, not just technical roles, to enable effective collaboration.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E3	English	"Workers should grasp basic concepts of how AI models function, are trained, and can solve complex problems."	Workers need to understand AI fundamentals, including model training and applications, to bridge gaps between technical and non-technical roles.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E3	English	"Creativity and innovation will remain crucial as areas where humans have a clear advantage over machines."	Creativity and the ability to innovate will be highly valued in roles where human skills surpass machine capabilities.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E3	English	"Understanding how to integrate AI and automation technologies into broader organizational goals will be important."	Interdisciplinary skills, including aligning AI with organizational strategies, are essential for workforce adaptability.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E3	English	"Being able to communicate effectively with teams across different functions ensures that technology aligns with real-world needs."	Effective cross-functional communication is vital for integrating automation technologies into	Impact on Human Roles & Employment	Human Factors & Skills

			practical, organizational contexts.		
AV_E3	English	"Adaptability will be key, as the rapid pace of technological advancement means roles and tools will evolve constantly."	Workers must embrace adaptability and lifelong learning to keep pace with evolving tools and roles in an automated world.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E4	German	"The future workforce will need a strong foundation in information technology, particularly in areas like data collection, analysis, and algorithm development."	Information technology skills, including data collection, analysis, and algorithm development, will be essential for workers in automation-driven industries.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E4	German	"Competencies in Human-Machine Interface (HMI) and cognitive sciences will also become increasingly important."	Skills in HMI and cognitive sciences will be critical for designing systems that are functional, intuitive, and psychologically acceptable to users.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E4	German	"There will be a growing need for skills in hardware-software integration to ensure seamless collaboration between the physical components of autonomous vehicles and their software systems."	Expertise in hardware-software integration will be crucial to enable seamless functionality in autonomous vehicles.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E4	German	"Workers will also need to understand and manage large-scale data processing to train and improve autonomous algorithms effectively."	Skills in managing large-scale data processing will be essential for training and improving autonomous systems.	Industry Readiness & Technology Advances	Human Factors & Skills
AV_E5	German	"This requires skills in software development, data analytics, and artificial intelligence."	Software development, data analytics, and AI expertise will be foundational skills for the workforce in autonomous driving.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E5	German	"The integration of AI in autonomous systems requires innovation and pushing the boundaries of real-time decision-making environments."	AI integration for real-time decision-making will demand innovative thinking and advanced machine learning competencies.	Industry Readiness & Technology Advances	Human Factors & Skills
AV_E5	German	"Protecting these vehicles from cyber threats requires skills in cybersecurity specific to automotive contexts, which is a relatively new field."	Automotive cybersecurity skills will become critical as autonomous systems rely heavily on interconnected, real-time data exchange.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E5	German	"We need more comprehensive and harmonized regulations that can keep up with the pace of technological development."	Harmonized and comprehensive regulations are necessary to align with the rapid advancements in autonomous driving technologies.	Regulatory Framework & Safety	Human Factors & Skills
AV_E6	German	"The industry will need people who understand not just software development but also how to integrate software with physical systems. A car is essentially becoming a robot—a fast, heavy robot operating in an open-world environment."	Future workforce demands will include expertise in integrating software with physical systems, treating cars as robotic entities in complex environments.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E6	German	"This requires expertise in robotics, artificial intelligence, machine learning, and sensor technology."	Key technical skills needed include robotics, artificial intelligence, machine learning, and	Impact on Human Roles & Employment	Human Factors & Skills

			sensor technology to advance automation capabilities.		
AV_E6	German	"At the same time, fields like cybersecurity are becoming increasingly important, especially as vehicles become more connected and rely on over-the-air updates."	Cybersecurity expertise is critical to protect connected and autonomous vehicles from hacking and external threats as reliance on digital systems grows.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E7	German	For the future workforce, the most critical skills and competencies will revolve around data science and computer science, especially in areas like AI and machine learning."	Data science and computer science skills, including AI and machine learning, will be crucial for future workforce readiness in autonomous driving.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E7	German	"Data scientists will play a key role because autonomous systems rely heavily on processing and analyzing vast amounts of data."	Expertise in data analysis and processing will be essential due to the data-intensive nature of autonomous systems.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E7	German	"On the other side, sales and marketing will also need to evolve. Autonomous driving is not just about building the technology—it's about selling it."	Workforce competencies must also focus on evolving sales and marketing strategies to ensure successful adoption of autonomous technologies.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E7	German	"OEMs will need skilled salespeople who can connect with customers on an emotional level, explain the benefits, and build trust in the technology."	Sales roles will require emotional intelligence and communication skills to build customer trust and promote autonomous driving adoption.	Public Perception & Trust in Automation	Human Factors & Skills
AV_E8	German	"The future workforce will need to focus heavily on skills related to AI and data management. The ability to train AI systems using vast amounts of data is going to be critical for advancing autonomous driving technologies."	Expertise in AI, data management, and training systems to handle complex real-world driving scenarios will be essential for the future workforce.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E8	German	"This includes expertise in developing algorithms that can handle the complexities of real-world driving scenarios."	Algorithm development skills for real-world complexity will be critical for the next generation of workers in automation industries.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E8	German	"There will be a growing need for competencies in hardware development, as creating autonomous solutions that integrate software and hardware seamlessly is essential."	The integration of hardware and software for full-stack autonomous solutions will demand advanced hardware development expertise.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E9	German	"The workforce will need strong AI and machine learning expertise, particularly in training systems to handle edge cases."	Future workforce requirements will emphasize AI and machine learning expertise, focusing on training systems to address rare, unpredictable scenarios.	Impact on Human Roles & Employment	Human Factors & Skills
AV_E9	German	"Beyond that, there's a need for interdisciplinary skills that combine traditional automotive engineering	Workers will need interdisciplinary skills, combining traditional automotive expertise	Impact on Human Roles & Employment	Human Factors & Skills

		with data science, sensor technology, and system architecture."	with data science, sensor technology, and system integration.		
AV_E9	German	"Understanding the integration of advanced computing power, neural networks, and vast datasets will be critical."	Proficiency in integrating advanced computing, neural networks, and large datasets will be essential for future roles in automation development.	Impact on Human Roles & Employment	Human Factors & Skills

Reduction: The future workforce for autonomous systems must adapt to an increased emphasis on AI, data science, and system integration. Skills in AI, machine learning, cybersecurity, and data management will be foundational as vehicles become more software driven. Cross-functional expertise combining technical, human-machine interaction, and customer-oriented skills is essential to bridge technical innovation with real-world application. Continuous learning, adaptability, and interdisciplinary training will be critical to meet evolving technological and operational demands. Moreover, effective workforce development requires restructured training programs focused on advanced analytics, algorithm design, and innovative problem-solving to drive the success of automation technologies.

AV_E1	German	"Concerns about job losses, especially for professional drivers, contribute to a cautious attitude toward automation."	Job displacement concerns, particularly for drivers, fuel skepticism about adopting automation technologies.	Impact on Human Roles & Employment	Industry Dynamics
AV_E1	German	"The focus is currently on shared mobility and freight transport, as private autonomous vehicles remain a longer-term goal."	Shared mobility and freight transport will lead automation efforts, while private autonomous vehicles are delayed due to cost and limited use cases.	Future Outlook & Strategic Vision	Industry Dynamics
AV_E1	German	"Pilot projects like Hamburg's '5-minute mobility' initiative represent critical milestones for urban deployments of autonomous shuttles."	Urban pilot projects demonstrating large-scale deployment, such as Hamburg's "5-minute mobility" initiative, are key for proving autonomous shuttle viability.	Future Outlook & Strategic Vision	Industry Dynamics
AV_E1	German	"Autonomous trucks for long-haul transport, which faces a driver shortage, represent a major milestone in addressing labor challenges."	Automation in long-haul freight transport addresses labor shortages and offers significant potential for efficiency gains.	Impact on Human Roles & Employment	Industry Dynamics
AV_E1	German	"Shared mobility services and freight applications are expected to see significant progress by 2027, while private autonomous vehicles remain a distant goal."	Shared mobility and freight automation are expected to advance by 2027, whereas private autonomous vehicles will see slower adoption due to practical challenges.	Future Outlook & Strategic Vision	Industry Dynamics
AV_E2	German	"While there are ongoing efforts by German OEMs and other players, the activity level varies, with some companies investing heavily and others stepping back."	German OEMs show varying levels of commitment to autonomous driving, with some heavily investing and others pulling back from the field.	Future Outlook & Strategic Vision	Industry Dynamics
AV_E2	German	"The legacy structures and processes of traditional OEMs often make it challenging to innovate quickly and effectively."	Legacy organizational structures in traditional OEMs slow down innovation compared to agile, tech-focused companies.	Impact on Human Roles & Employment	Industry Dynamics
AV_E2	German	"Rigid corporate structures and collective agreements can hinder flexibility and innovation, making it	Organizational rigidity and inflexibility in legacy companies impede innovation and	Impact on Human Roles & Employment	Industry Dynamics

		harder to compete with tech-first companies."	competitiveness against agile tech firms.		
AV_E8	German	"Manufacturers like Mercedes, BMW, and Tesla are pushing hard in this direction, but full-scale adoption will take more time."	Leading manufacturers are advancing towards Level 4 autonomy, but broader adoption remains a longer-term challenge.	Industry Readiness & Technology Advances	Industry Dynamics
AV_E8	German	"If a major player—be it a Tesla, a German OEM, or even a Chinese company—can bring a functional Level 4 system to market sooner, it could shake up the industry and accelerate progress across the board."	Early market entry by a major player with a functional Level 4 system could significantly disrupt and accelerate progress in the industry.	Future Outlook & Strategic Vision	Industry Dynamics
AV_E9	German	"Tesla, instead of geofencing, focuses on broader adaptability through a camera-based system with relatively low-cost sensors. They collect vast amounts of data from their global fleet to train their AI models, aiming for scalability and point-to-point navigation in a wide range of conditions."	Tesla's approach emphasizes scalability and broader adaptability by using camera-based systems and fleet data, but these systems still fall short of achieving full autonomy.	Industry Readiness & Technology Advances	Industry Dynamics

Reduction: Industry dynamics in autonomous driving are shaped by diverse efforts and challenges among traditional OEMs and new tech-driven competitors. Shared mobility and freight transport remain primary areas of focus, with pilot programs like Hamburg's urban shuttle initiative highlighting progress in real-world applications. While traditional OEMs often face structural rigidities and slower innovation cycles, companies like Tesla push agile strategies to advance automation capabilities. Private autonomous vehicles are expected to see slower adoption due to cost and practical constraints. The industry's competitive landscape underscores the importance of flexibility, investment in innovation, and addressing workforce concerns, particularly regarding job displacement and public skepticism. These dynamics highlight a transitional phase, with varied strategies defining progress towards broader deployment.

AV_E1	German	"Autonomous vehicles require advanced infrastructure, including reliable communication systems and urban adaptations like dedicated lanes or parking areas for autonomous shuttles."	Infrastructure development, such as communication systems and urban adaptations, is critical to supporting autonomous vehicle operations.	Industry Readiness & Technology Advances	Infrastructure Gaps
AV_E1	German	"Current infrastructure is not uniformly equipped to support widespread autonomous driving, especially outside urban centers."	The lack of uniform infrastructure readiness, especially in non-urban areas, limits widespread adoption of autonomous vehicles.	Industry Readiness & Technology Advances	Infrastructure Gaps
AV_E2	German	"In Germany, the readiness of technology for Level 4 is mixed, with infrastructure remaining a critical bottleneck."	In Germany, Level 4 technology progress is constrained by inadequate infrastructure, which limits scalability.	Industry Readiness & Technology Advances	Infrastructure Gaps
AV_E2	German	"The lack of suitable infrastructure is already a challenge for Level 3 systems, making scaling Level 4 systems even more difficult."	Insufficient infrastructure hinders the progression from Level 3 to Level 4 systems, requiring substantial upgrades for scalability.	Industry Readiness & Technology Advances	Infrastructure Gaps
AV_E2	German	"Germany is still in the process of developing the necessary infrastructure and regulatory frameworks to support Level 4 systems."	Developing infrastructure and regulatory frameworks for Level 4 systems is still a work in progress in Germany, hindering readiness.	Regulatory Framework & Safety	Infrastructure Gaps
AV_E3	English	"Infrastructure upgrades, such as advanced connectivity (6G or beyond), will enable real-time communication between vehicles and infrastructure."	Infrastructure advancements, like 6G, are essential for real-time communication	Industry Readiness & Technology Advances	Infrastructure Gaps

			and improved safety in autonomous operations.		
AV_E4	German	"Infrastructure upgrades, such as vehicle-to-infrastructure communication systems and smart road features, will play a key role in enabling higher levels of automation."	Infrastructure improvements, including V2I systems and smart road features, are critical to supporting advanced levels of automation.	Industry Readiness & Technology Advances	Infrastructure Gaps
AV_E5	German	"Establishment of standards for vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications is critical for seamless and safe interaction."	Clear and consistent standards for V2I and V2V communications are essential for ensuring the safe operation of autonomous systems.	Industry Readiness & Technology Advances	Infrastructure Gaps
Reduction: Infrastructure gaps present significant challenges to the advancement and scalability of autonomous vehicles. Current infrastructure, particularly in non-urban areas, lacks the necessary readiness to support widespread deployment. Upgrades in vehicle-to-infrastructure (V2I) communication systems, real-time connectivity such as 6G, and smart road features are critical for enabling advanced automation. In Germany, the progression of Level 4 systems is hindered by insufficient infrastructure and regulatory readiness. Establishing clear standards for V2I and vehicle-to-vehicle (V2V) interactions will be essential for safe and efficient operations. Addressing these gaps through coordinated development is crucial to unlocking the full potential of autonomous driving systems.					
AV_E1	German	"Challenges remain in integrating these components into functional, reliable systems."	Component integration and system-wide reliability are primary barriers to achieving commercial readiness.	Industry Readiness & Technology Advances	Integration Challenges
AV_E1	German	"One of the most significant challenges lies in the interplay between different streams necessary for the successful adoption of autonomous driving."	Achieving seamless integration of technology, infrastructure, regulations, and societal acceptance is essential for successful automation adoption.	Industry Readiness & Technology Advances	Integration Challenges
AV_E3	English	"The progress toward full autonomy depends heavily on factors like public trust, government regulations, and technological advancements."	Progress in full autonomy is contingent on public trust, regulatory evolution, and technology improvements.	Regulatory Framework & Safety	Integration Challenges
Reduction: Integration challenges remain a significant barrier to the widespread adoption of autonomous driving. Ensuring seamless integration of components into functional and reliable systems is essential for achieving commercial readiness. This involves addressing the interplay between technology, infrastructure, regulations, and societal acceptance. Progress toward full autonomy is also dependent on building public trust, evolving regulatory frameworks, and advancing technological capabilities to create cohesive and scalable solutions.					
AV_E1	German	"There is an unrealistic expectation from the public that autonomous systems will deliver a perfect safety record."	The public expects unrealistic levels of safety from automation, necessitating careful management of expectations.	Public Perception & Trust in Automation	Public Expectation
AV_E1	German	"Communicating the safety benefits—such as reducing accidents caused by human error—while being transparent about the limitations, is crucial."	Clear communication about safety benefits and limitations is essential to build trust and manage public expectations.	Public Perception & Trust in Automation	Public Expectation
AV_E1	German	"Social narrative and communication play a significant role. There needs to be a positive narrative about how autonomous technologies will improve everyday life, backed by real, tangible results"	A positive narrative highlighting the societal benefits of automation—such as mobility, congestion reduction, and sustainability—helps build public trust.	Public Perception & Trust in Automation	Public Expectation

AV_E2	German	"Public perception of automation technologies, particularly autonomous driving, is a mix of fascination and skepticism."	Public opinion on autonomous driving is divided between intrigue and concerns about safety and social impact.	Public Perception & Trust in Automation	Public Expectation
AV_E3	English	"The most important factor for people to accept autonomous driving is safety. People need to feel confident that the system is safe and won't put their lives at risk."	Safety is the primary factor influencing public acceptance, requiring assurance of reliability and risk-free operation.	Public Perception & Trust in Automation	Public Expectation
AV_E4	German	"Clear communication from manufacturers about the capabilities and limitations of the technology will be essential in gaining public confidence."	Open and honest communication from manufacturers about technology capabilities and limitations is key to fostering trust.	Public Perception & Trust in Automation	Public Expectation
AV_E5	German	"Effective communication about the benefits and limitations of automation is critical to setting realistic expectations."	Clear communication about both the benefits and limitations of automation is necessary to manage public expectations effectively.	Public Perception & Trust in Automation	Public Expectation
AV_E7	German	"This includes addressing the ethical questions around decision-making in complex scenarios and being transparent about how these decisions are programmed into the AI."	Ethical considerations and transparency in AI decision-making are critical for building trust and regulatory acceptance.	Regulatory Framework & Safety	Public Expectation
AV_E9	German	"In Europe, building trust requires more transparent communication, demonstration projects, and a gradual introduction of the technology to showcase its safety and reliability."	Building public trust in Europe requires transparency, demonstration projects, and a gradual rollout of autonomous systems to highlight safety and reliability.	Public Perception & Trust in Automation	Public Expectation
AV_E9	German	"Manufacturers and policymakers must also emphasize safety and reliability while addressing concerns about job displacement or potential risks."	Collaboration between manufacturers and policymakers is critical to highlight safety, reliability, and address societal concerns, including job displacement.	Impact on Human Roles & Employment	Public Expectation
Reduction: Public expectations for autonomous driving systems are shaped by concerns about safety and transparency. Many anticipate flawless safety records, emphasizing the need for clear communication about the technology's benefits and limitations. Building trust requires consistent messaging on societal advantages, such as reduced accidents and improved mobility, coupled with open discussions about challenges. Demonstration projects and gradual rollouts in Europe help address these expectations, fostering confidence and public support.					
AV_E1	German	"Social acceptance and societal dialog are crucial factors. While there is general enthusiasm for the concept of autonomous driving, concerns about safety, ethical decision-making..."	Societal concerns regarding safety, ethics, and job displacement must be addressed to build public trust in autonomous driving technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"Honest communication about the limitations of these systems is crucial to managing public expectations."	Transparency about system limitations is essential to align public expectations with the reality of automation capabilities.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"The public perception of automation technologies is generally positive, though it varies across different demographic groups and societal factors."	Public perception of automation is broadly positive but varies by demographic factors and societal context.	Public Perception & Trust in Automation	Public Perception & Trust

AV_E1	German	"Older individuals often value autonomous technologies for the increased mobility it could provide, such as enabling them to reach places they couldn't access otherwise."	Older demographics see automation as a tool to enhance mobility and independence.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"Younger, more tech-savvy generations are typically enthusiastic about the idea of automation and its promise of convenience and innovation."	Younger generations are generally enthusiastic about the convenience and innovation offered by automation.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"Willingness to adopt autonomous vehicles can be hampered if the costs are perceived as too high."	High costs can deter public adoption of autonomous technologies despite general enthusiasm.	Future Outlook & Strategic Vision	Public Perception & Trust
AV_E1	German	"Pilot projects, like autonomous shuttles, often generate positive feedback when they demonstrate tangible benefits, such as improving urban mobility or reducing congestion."	Demonstrating tangible benefits through pilot projects helps build public trust in automation.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"Even small issues—such as parking spaces being removed for shuttle stops—can quickly dampen acceptance if not managed through proper public engagement and dialog."	Public engagement and managing local disruptions are key to maintaining trust and acceptance of automation.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"Fostering trust and acceptance requires an ongoing effort to educate the public about the benefits, limitations, and safeguards of automation."	Education, transparency, and public dialog are crucial to building trust and sustaining positive public perception of automation technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E1	German	"Ease of use is another critical factor. For the technology to gain widespread acceptance, it needs to integrate seamlessly into people's lives."	Seamless integration and user-friendly design are vital for widespread adoption of autonomous technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"People are generally intrigued by the concept of autonomous driving but remain cautious about safety, ethical concerns, and the potential impact on jobs."	Public interest in autonomous driving is tempered by concerns about safety, ethics, and job displacement.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"Convincing the public of the reliability and value of these systems will require time, transparent communication, and the demonstration of tangible benefits through pilot projects."	Building public trust in autonomous systems demands transparent communication and successful pilot project demonstrations.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"People may initially express enthusiasm in surveys but change their views when considering deeper issues like job losses or accidents."	Enthusiasm for automation can wane when safety risks or job displacement concerns are highlighted.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"In Germany and Europe, the population tends to be more conservative and cautious, taking time to trust new technologies."	European populations are generally more conservative and require longer timelines to build trust in new technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"The younger generation may be more open to digitization and artificial intelligence, but older demographics might find the idea appealing for practical reasons, like mobility in rural areas."	Younger demographics embrace automation more readily, while older individuals value it for practical benefits like increased mobility in rural settings.	Public Perception & Trust in Automation	Public Perception & Trust

AV_E2	German	"Acceptance among the population will depend heavily on exposure and familiarity with autonomous vehicles."	Public acceptance of autonomous vehicles will grow through exposure and familiarity with the technology in real-world applications.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"Incentives may be necessary to encourage people to try autonomous systems, such as subsidized or free rides."	Subsidies or incentives can help introduce autonomous technologies and build initial trust among the population.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"Older populations might also benefit from autonomous mobility, particularly in rural areas where public transportation is limited."	Older individuals, especially in rural areas, could see autonomous vehicles as a means to regain mobility and independence.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"Addressing public perception and acceptance will be critical for widespread adoption of autonomous systems."	Public trust and acceptance are key factors in the successful adoption of autonomous technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E2	German	"Demonstrating safety, reliability, and tangible benefits through pilot projects and phased rollouts will be necessary to achieve widespread adoption."	Pilot projects and phased rollouts showcasing safety and benefits are essential for gaining public trust and encouraging adoption.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E3	English	"Public perception and trust in automation technologies are generally positive but vary based on geography, demographics, and exposure."	Public trust in automation is influenced by regional, demographic, and exposure-related factors, with a generally positive but cautious outlook.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E3	English	"In regions where autonomous vehicles are tested or deployed, public trust has grown incrementally as people experience these systems firsthand."	Firsthand exposure to autonomous technologies in regions with pilot projects or deployments helps incrementally build public trust.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E3	English	"Incidents like accidents involving autonomous systems can significantly impact public perception, causing skepticism to resurface."	Accidents involving autonomous systems can erode public trust, even in areas with prior positive exposure to these technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E3	English	"In Europe, the public is cautious and reserved, influenced by stringent safety regulations and a cultural emphasis on thoroughness over speed of adoption."	Europe's cautious cultural and regulatory approach fosters long-term trust but slows the adoption of autonomous systems.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E3	English	"Younger generations, familiar with digital technologies, tend to be more optimistic about automation and its benefits."	Younger demographics are generally more optimistic about automation due to their familiarity with digital technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E3	English	"Older generations can appreciate the convenience of autonomous vehicles, especially for improving mobility in later stages of life."	Older individuals may value autonomous vehicles for their potential to enhance mobility during later stages of life, despite initial skepticism.	Public Perception & Trust in Automation	Public Perception & Trust

AV_E3	English	"Alongside safety, comfort is also critical. Nobody wants a car that accelerates too quickly, brakes too harshly, or takes sudden turns."	Comfort and smooth driving experiences are key to building trust and increasing adoption of autonomous systems.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E4	German	"Public perception of automation technologies, especially autonomous driving, is still relatively cautious, particularly in Germany and Europe."	Public perception of autonomous driving in Europe is cautious, with a strong focus on safety and skepticism about technological readiness.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E4	German	"In Germany, where there is a strong focus on engineering precision and safety, the public is hesitant about fully trusting autonomous systems."	Germany's emphasis on precision and safety contributes to public hesitation in trusting autonomous systems, particularly at higher levels of automation.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E4	German	"If people were to use a Level 4 or Level 5 vehicle, they would need to have confidence in the manufacturer behind the system."	Trust in manufacturers is essential for public acceptance of high-level autonomous vehicles, such as Level 4 and Level 5 systems.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E4	German	"The most important factor for acceptance is safety. People need to feel confident that autonomous systems can perform as safely, if not more safely, than human drivers."	Public acceptance hinges on ensuring that autonomous systems demonstrate safety equal to or greater than human drivers.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E4	German	"Ensuring a proven safety track record through testing and real-world data will be key to building this trust."	Demonstrating a strong safety track record through extensive testing and real-world data is crucial for gaining public trust.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E4	German	"People need to understand how the systems work, how decisions are made by the autonomous vehicle, and how safety is ensured."	Transparency in how autonomous systems work and make decisions is vital for building trust and addressing public concerns.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E5	German	"Public perception and trust in automation technologies are mixed, with fascination for potential benefits but skepticism about reliability and safety."	Public perception of automation technologies is divided between excitement for their benefits and skepticism due to concerns about safety and reliability.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E5	German	"Skepticism is fueled by high-profile incidents involving autonomous vehicles."	Public trust is impacted by high-profile incidents, which highlight safety concerns around autonomous technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E5	German	"Building trust involves demonstrating safety and reliability through transparent and rigorous testing."	Demonstrating safety and reliability through clear and rigorous testing is essential to gaining public trust.	Regulatory Framework & Safety	Public Perception & Trust
AV_E5	German	"Early adopters and positive case studies can influence public opinion, but this is a gradual process requiring consistent effort and proven results."	Early successes and positive case studies can gradually shift public opinion, but building trust requires consistent effort and demonstrable reliability.	Future Outlook & Strategic Vision	Public Perception & Trust

AV_E5	German	"Gaining public trust and acceptance through successful pilot programs and transparent testing will be a significant milestone."	Public trust and acceptance must be built through pilot programs and transparent testing to demonstrate the safety and effectiveness of autonomous systems.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E6	German	"The current public perception and trust in automation technologies within the industry is still evolving and somewhat mixed. On one hand, there is curiosity and interest in the potential benefits, like convenience, safety, and increased accessibility for individuals who may not be able to drive."	Public perception of automation is mixed, with interest in potential benefits such as safety, convenience, and accessibility, especially for those unable to drive.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E6	German	"Public trust often hinges on whether the technology can demonstrate consistent safety and reliability, which is a challenge given the complexity of real-world environments."	Demonstrating consistent safety and reliability is critical for gaining public trust, but complex real-world environments make this challenging.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E6	German	"Interestingly, public perception tends to shift positively once people experience the technology firsthand. For instance, as automated vehicles are introduced into controlled environments like Waymo's operations in suburban Phoenix, users often find them to be safe and convenient, which helps build trust."	Firsthand experiences with autonomous technologies, such as Waymo's operations, often improve public perception by demonstrating safety and convenience.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E6	German	"That said, widespread acceptance will largely depend on solving the safety concerns and proving that these systems are more reliable than human drivers."	Solving safety concerns and proving systems are more reliable than human drivers are essential for widespread acceptance of automation technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E6	German	"I think it's also about showing people the practical value of the technology. Nobody enjoys sitting in rush-hour traffic or dealing with stop-and-go congestion. If we can take these frustrating experiences off the table, people will naturally see the benefits."	Highlighting the practical value, such as reducing traffic frustration and congestion, will encourage public acceptance of autonomous vehicles.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E6	German	"This is especially important because, right now, many don't fully understand what the technology can do. It's a bit like asking someone to describe the moon without ever having seen it—it's hard to imagine what's possible."	Public understanding of the capabilities and limitations of autonomous systems is limited, making it harder for people to trust or imagine their potential benefits.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"On the other side, customer acceptance is still a huge hurdle. Trust in the technology is low."	Low trust and acceptance of autonomous technology among customers remain significant barriers to adoption.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"Many people won't even use simple automated features like parking aids, let alone a Level 5 autonomous vehicle without a steering wheel."	Customers' reluctance to use even basic automated features highlights the steep challenges in building trust for fully autonomous systems.	Public Perception & Trust in Automation	Public Perception & Trust

AV_E7	German	"OEMs need to provide hands-on experiences, like test drives or pilot programs, so customers can see the benefits firsthand."	OEMs can build customer trust by offering hands-on experiences, pilot programs, and test drives to demonstrate the technology's safety and benefits.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"It's all about creating confidence in the technology through personal interaction and real-world demonstrations."	Personal interaction and real-world demonstrations are critical to building public confidence in autonomous technology.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"The current public perception and trust in automation technologies are still very cautious and reserved, especially here in Germany."	Public perception of automation technologies remains cautious, particularly in regions like Germany, due to skepticism about reliability.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"The most important factors for acceptance among the population are safety, trust, and hands-on experience with the technology."	Public acceptance of autonomous driving depends on safety, trust, and direct exposure to the technology through hands-on experiences.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"Regulations play a role in acceptance. If people see that the EU or other regulatory bodies have implemented strict guidelines and that the vehicles comply with these, it creates a sense of security."	Strong regulatory frameworks and compliance with stringent safety standards enhance public confidence in autonomous vehicles.	Regulatory Framework & Safety	Public Perception & Trust
AV_E7	German	"Combining these elements—safety, trust, and strong regulatory backing—will be essential to get the public on board with autonomous driving."	Safety, trust, and robust regulatory support are essential for fostering public acceptance of autonomous vehicles.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E7	German	"Gaining customer trust is perhaps the most crucial milestone. Even if the technology is fully developed and regulations are in place, autonomous vehicles will only succeed if customers feel confident in using them."	Building customer trust is vital for adoption, requiring confidence in safety, reliability, and successful use cases.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"Finally, public trust and acceptance are ongoing concerns. Customers often have initial fears and reservations about autonomous driving, though our studies indicate that trust grows after a few experiences with the technology."	Public trust in autonomous driving remains low initially but improves with firsthand experience of the technology.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"Public trust also plays a big role in safety. Things like informing passengers about what the vehicle is doing—why it's braking, turning, or slowing down—can make a significant difference in building confidence."	Public trust is integral to safety, and transparency about vehicle actions helps build passenger confidence.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"Public perception of automation technologies is still somewhat mixed. On one hand, there's skepticism and fear—many people are hesitant about trusting autonomous systems, especially at higher levels of automation."	Public perception of automation is divided, with skepticism and fear dominating, especially concerning high levels of autonomy.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"But on the other hand, once they have firsthand experience with the technology, that skepticism often	Firsthand experience with autonomous systems can significantly	Public Perception & Trust in Automation	Public Perception & Trust

		diminishes. For example, studies and driving simulations show that after just a few trips in an autonomous vehicle, people tend to feel more comfortable and begin trusting the system."	reduce skepticism, as familiarity increases comfort and trust.		
AV_E8	German	"In Germany specifically, I think there's a general tendency to be a bit more cautious. Some people here still prefer manual transmissions, so the idea of a completely autonomous car can feel like a big leap."	In Germany, public perception is particularly cautious, with cultural preferences for manual systems making full automation seem like a significant shift.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"That said, it's also clear that there's a growing openness, particularly among younger or more digitally savvy individuals."	Younger and digitally inclined individuals are more open to embracing autonomous technologies, signaling a generational shift in acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"I think the most important factors for public acceptance are safety, cost, and the overall experience provided by the technology."	Public acceptance hinges on three key factors: safety, affordability, and the user experience of autonomous systems.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E8	German	"In the end, people need to see real benefits—safety, convenience, and value—for this technology to gain broad acceptance."	Broad acceptance of autonomous driving depends on clear, tangible benefits in safety, convenience, and value for users.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E9	German	"Another hurdle is public perception and trust, as well as integrating these systems into existing mobility infrastructures in ways that are economically and socially beneficial."	Public perception and trust, along with seamless integration into existing infrastructures, are critical challenges for successful adoption of automation.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E9	German	"Europe and Germany, on the other hand, tend to be more cautious, focusing heavily on public safety and requiring extensive approval processes."	Europe and Germany adopt a cautious approach, prioritizing public safety with stringent approval processes for autonomous technologies.	Regulatory Framework & Safety	Public Perception & Trust
AV_E9	German	Public perception in regions like Germany and Europe tends to be more cautious compared to the U.S. and China."	Public perception in Europe is cautious compared to the U.S. and China, where openness to innovation and new technologies is greater.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E9	German	"People are less tech-savvy and more skeptical about new technologies, particularly when it comes to safety."	European populations are more skeptical and less tech-savvy, especially regarding safety in automation technologies.	Public Perception & Trust in Automation	Public Perception & Trust
AV_E9	German	"In contrast, countries like China are more open to innovation and have a greater willingness to test and adopt new systems."	Countries like China demonstrate higher openness to innovation and are more willing to adopt and test automation technologies.	Public Perception & Trust in Automation	Public Perception & Trust

AV_E9	German	"Experience is key. People need to see and feel the benefits firsthand, whether through demo projects in cities or consumer education initiatives."	Hands-on experience, such as demo projects or consumer education, is essential for fostering public trust and understanding of automation technologies.	Public Perception & Trust in Automation	Public Perception & Trust
Reduction: Public acceptance of autonomous driving is shaped by trust, safety concerns, and exposure to the technology. Building confidence requires transparent communication about the system and its reliability and showcasing practical benefits. Societal acceptance varies across demographics, with younger generations and tech-savvy individuals showing greater openness. Real-world demonstrations, pilot programs, and consumer education initiatives are critical in overcoming skepticism and fostering familiarity. A unified regulatory framework and clear standards also play a role in establishing trust and ensuring safety, creating a solid foundation for widespread adoption.					
AV_E1	German	"Other regions, such as the U.S., have advanced further in system-level deployment."	The U.S. leads in system-level deployment of automation technologies, emphasizing regional disparities in progress.	Future Outlook & Strategic Vision	Regional Disparities
AV_E1	German	"The lack of cross-border testing capabilities due to differing national requirements makes it difficult to test vehicles realistically across Europe."	Differing national regulations restrict cross-border testing, limiting realistic assessments of autonomous vehicle operations.	Regulatory Framework & Safety	Regional Disparities
AV_E1	German	"In Europe, the regulatory framework is highly structured and stringent, ensuring safety but slowing innovation and deployment."	Europe's stringent homologation and type-approval system ensures safety but delays innovation and deployment of autonomous technologies.	Regulatory Framework & Safety	Regional Disparities
AV_E1	German	"The United States operates under a voluntary self-certification model, allowing faster innovation but with higher risks."	The U.S. regulatory model prioritizes speed and innovation through voluntary self-certification but increases liability risks for manufacturers.	Regulatory Framework & Safety	Regional Disparities
AV_E1	German	"China enables rapid testing and deployment in specific regions under controlled conditions, often supported by the state."	China's directive regulatory approach supports rapid advancements in automation within restricted areas, often backed by government support.	Regulatory Framework & Safety	Regional Disparities
AV_E1	German	"In the U.S., road systems tend to be more uniform, which makes testing and implementation of automation technologies easier."	Uniform road infrastructure in the U.S. facilitates easier testing and implementation of autonomous technologies.	Industry Readiness & Technology Advances	Regional Disparities
AV_E1	German	"In Europe, the road network is more complex, requiring sophisticated systems and stricter regulations."	Europe's complex road network necessitates advanced automation systems and stricter regulatory oversight.	Industry Readiness & Technology Advances	Regional Disparities
AV_E1	German	"Europe and the U.S. differ in how liability and safety requirements are handled, with Europe focusing on pre-approval and the U.S. placing post-deployment burden on manufacturers."	Liability approaches differ: Europe minimizes post-deployment risk through pre-approval, while the U.S. shifts the burden to manufacturers post-deployment.	Regulatory Framework & Safety	Regional Disparities

AV_E1	German	"China's designated urban areas for testing allow for quicker advancements but lack flexibility for nationwide expansion without government oversight."	China's regulatory model enables rapid local advancements but limits nationwide scalability due to centralized government oversight.	Regulatory Framework & Safety	Regional Disparities
AV_E1	German	"Internationally, harmonization of regulations across Europe and globally is another milestone, with UNECE regulations expected by 2026."	Global and European regulatory harmonization, anticipated by 2026 under UNECE, is essential for cross-border operations of autonomous vehicles.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"Efforts are more concentrated in hubs like California and China, where Silicon Valley fosters innovation and state-driven initiatives accelerate progress."	Regional hubs like California and China are driving autonomous innovation due to supportive ecosystems and regulatory frameworks.	Future Outlook & Strategic Vision	Regional Disparities
AV_E2	German	"Harmonization across European countries is limited, and other global players like China and the U.S. are approaching the issue with very different regulatory philosophies."	Fragmented global and European regulatory approaches hinder scalability and deployment of autonomous driving technologies.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"Regulatory approval processes need to become more streamlined and harmonized across federal states in Germany, but also on a European level."	Harmonization of regulatory processes across German states and within Europe is essential to eliminate inefficiencies and inconsistencies.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"In the U.S., decentralized regulation allows rapid progress in states like California but creates disparities in readiness and oversight."	Decentralized regulatory models, as seen in the U.S., foster innovation in some regions but create inconsistencies nationwide.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"China's state-driven regulatory process allows for quicker implementation aligned with government priorities."	China's centralized regulatory model enables faster implementation of autonomous technologies when aligned with government strategies.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"In Europe, including Germany, the regulatory framework is heavily structured and safety-oriented, emphasizing homologation and type approval."	Europe's safety-oriented regulatory framework prioritizes homologation and type approval, ensuring safety but slowing innovation and scalability.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"In the United States, states have significant autonomy to set their own rules for autonomous vehicles, with California leading in testing and deployment."	The U.S. adopts a decentralized regulatory approach, with leading states like California driving autonomous vehicle innovation and deployment.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"The U.S. follows a voluntary self-certification model, where manufacturers declare their systems are safe, enabling faster deployment but inconsistencies in oversight."	The voluntary self-certification model in the U.S. accelerates deployment but leads to inconsistencies in safety and regulatory standards.	Regulatory Framework & Safety	Regional Disparities

AV_E2	German	"In China, the regulatory environment is highly centralized and state-driven, aligning regulations with national priorities to accelerate testing and deployment."	China's centralized and state-driven regulatory model facilitates rapid progress in autonomous technology, aligned with national strategic priorities.	Regulatory Framework & Safety	Regional Disparities
AV_E2	German	"China's top-down approach may overlook societal concerns, such as job displacement, prioritizing technological leadership over public sentiment."	China's emphasis on centralized control prioritizes technology leadership, sometimes at the expense of addressing societal concerns.	Public Perception & Trust in Automation	Regional Disparities
AV_E2	German	"Europe's cautious and safety-first mindset contrasts with the U.S.'s innovation-driven and market-oriented approach, while China's centralized control enables swift decision-making."	Regional regulatory approaches reflect cultural and political differences: Europe focuses on safety, the U.S. on innovation, and China on centralized control.	Comparative Analysis	Regional Disparities
AV_E2	German	"In China, decisions around automation are often made top-down by the government, and public acceptance is more or less guided by this centralized approach."	In China, public acceptance of automation is heavily influenced by the government's top-down decision-making approach.	Public Perception & Trust in Automation	Regional Disparities
AV_E2	German	"Harmonizing these elements, particularly in regions like Europe, will be crucial to enabling cross-border testing and scaling."	Cross-border testing and scaling in Europe depend on harmonized infrastructure and regulatory approaches.	Regulatory Framework & Safety	Regional Disparities
AV_E3	English	"Regulations pose a significant challenge, particularly in the EU, where strict data privacy laws and approval processes slow innovation compared to more flexible U.S. frameworks."	Strict EU regulations on data privacy and system approvals hinder innovation compared to the more flexible U.S. regulatory environment.	Regulatory Framework & Safety	Regional Disparities
AV_E3	English	"In Europe, regulations are stringent and highly structured, emphasizing safety and compliance through rigorous homologation and type-approval processes."	Europe's structured regulatory framework prioritizes safety through stringent approval processes, which can slow innovation and commercialization.	Regulatory Framework & Safety	Regional Disparities
AV_E3	English	"In the U.S., each state has significant autonomy to create its own regulations, leading to variation in readiness and deployment."	The decentralized regulatory model in the U.S. allows for state-specific policies, creating disparities in readiness and adoption of autonomous systems.	Regulatory Framework & Safety	Regional Disparities
AV_E3	English	"The U.S. follows a self-certification model, where companies declare their systems are safe without needing pre-market approval."	The U.S. self-certification model accelerates innovation but poses higher risks due to the lack of mandatory pre-market testing.	Regulatory Framework & Safety	Regional Disparities
AV_E3	English	"China operates under a centralized, state-driven regulatory framework, designating specific cities or regions as testing hubs."	China's centralized regulatory approach facilitates rapid testing and scaling in designated regions, driven by government priorities.	Regulatory Framework & Safety	Regional Disparities

AV_E3	English	"China's approach limits public input and creates a top-down model of adoption."	The centralized, government-driven model in China prioritizes progress but limits public involvement and transparency.	Public Perception & Trust in Automation	Regional Disparities
AV_E3	English	"Harmonizing global standards for testing and approval processes is another milestone to allow for cross-border operations and broader deployment."	Aligning global regulations and testing standards is critical to facilitate international deployment and reduce costs.	Regulatory Framework & Safety	Regional Disparities
AV_E4	German	"One critical requirement is the creation of unified and stable regulations across countries and regions, particularly within the EU."	Unified and stable regulations across regions, especially in the EU, are essential to provide clarity and stability for manufacturers.	Regulatory Framework & Safety	Regional Disparities
AV_E4	German	"In China, the approach is more aggressive, with rapid progress and significant government support, building infrastructure with autonomous driving in mind."	China's centralized approach, supported by government and tailored infrastructure, accelerates autonomous driving adoption but limits public input.	Regulatory Framework & Safety	Regional Disparities
AV_E4	German	"This centralized approach allows for faster adoption of autonomous technologies, but it also comes with limitations, such as a lack of public input and oversight."	The centralized model in China facilitates rapid adoption but lacks transparency and public engagement.	Public Perception & Trust in Automation	Regional Disparities
AV_E4	German	"In Europe, the regulatory environment is more cautious and heavily focused on safety and public trust, with stricter data privacy laws."	Europe prioritizes safety and public trust, with stricter data privacy laws that slow implementation but ensure higher transparency and compliance.	Regulatory Framework & Safety	Regional Disparities
AV_E4	German	"Europe is working toward unified standards and regulations within the EU, which would help ease the process for manufacturers and promote consistency."	Efforts to unify EU regulations aim to simplify compliance for manufacturers and foster consistency across member states.	Regulatory Framework & Safety	Regional Disparities
AV_E4	German	"In the United States, regulations vary significantly from state to state, with some states like California allowing extensive testing and others being more restrictive."	The U.S. regulatory environment is fragmented, with progressive states like California enabling rapid testing and restrictive states creating disparities.	Regulatory Framework & Safety	Regional Disparities
AV_E4	German	"The U.S. generally takes a more flexible approach, allowing for quicker innovation, but this can create inconsistency in safety standards and operational conditions."	The flexible regulatory approach in the U.S. accelerates innovation but leads to inconsistent safety standards and operational practices across states.	Regulatory Framework & Safety	Regional Disparities
AV_E5	German	"In the United States, the regulatory environment is somewhat unregulated at the federal level, allowing manufacturers leeway to develop and test new technologies with fewer constraints."	The U.S. federal regulatory framework is less stringent, offering manufacturers greater flexibility to innovate and test autonomous technologies.	Regulatory Framework & Safety	Regional Disparities
AV_E5	German	"In the European Union, the regulatory framework is much more stringent and uniform across	The EU's stringent and uniform regulatory framework requires	Regulatory Framework & Safety	Regional Disparities

		member states, demanding extensive validation and testing before deployment."	thorough validation and testing, ensuring safety but slowing deployment.		
AV_E5	German	"This involves creating a regulatory framework that major players like the U.S., EU, and China can align with, which will provide the basis for consistent development and deployment worldwide."	Regulatory alignment among global regions (e.g., U.S., EU, China) is essential for consistent and streamlined deployment of autonomous technologies.	Regulatory Framework & Safety	Regional Disparities
AV_E6	German	"In Europe and Germany, for instance, we have a centralized type-approval process where vehicles are rigorously tested by an external body before they're allowed on the road. In the U.S., it's more of a self-certification model—manufacturers conduct their own safety tests and certify their vehicles."	Regulatory approaches vary globally, with Europe favoring centralized type approval and the U.S. adopting a self-certification model, creating fragmentation.	Regulatory Framework & Safety	Regional Disparities
AV_E6	German	"In Europe, including Germany, the regulatory framework relies on a centralized type-approval system. This means that vehicles must undergo extensive testing and approval by an external body before they are allowed on the road. It's a rigorous process designed to ensure safety and compliance with strict standards."	Europe uses a centralized type-approval system that mandates extensive external testing and approval for autonomous vehicles, ensuring high safety and compliance standards but slowing down deployment.	Regulatory Framework & Safety	Regional Disparities
AV_E6	German	"In contrast, the United States follows a self-certification system, where manufacturers conduct their own safety tests and certify that their vehicles meet legal requirements. While this allows for faster development and deployment, it relies heavily on manufacturers' accountability."	The U.S. employs a self-certification model that enables faster development and deployment but relies on manufacturers' accountability, creating potential risks in ensuring consistent safety standards.	Regulatory Framework & Safety	Regional Disparities
AV_E6	German	"Additionally, in the U.S., regulations can vary significantly at the state level. For example, what's permissible in California might differ from Pennsylvania or Texas."	U.S. state-level regulatory variation creates inconsistencies, making it challenging for manufacturers to operate seamlessly across the country.	Regulatory Framework & Safety	Regional Disparities
AV_E7	German	"First, there needs to be a clear and unified set of standards, particularly across regions like the EU, to ensure a consistent foundation for all OEMs."	Unified standards across regions, especially in the EU, are necessary to create a consistent regulatory foundation for manufacturers.	Regulatory Framework & Safety	Regional Disparities
AV_E7	German	"The EU already has stricter regulations compared to places like the USA, where companies can experiment more freely, but there's still work to be done in defining how these ethical decisions are managed."	While the EU has stricter regulations, further clarity is needed on managing ethical decisions in autonomous vehicle operations.	Regulatory Framework & Safety	Regional Disparities
AV_E7	German	"In the EU, the regulations are much stricter compared to the USA, where companies can experiment and deploy technologies like robo-taxis more freely."	The EU enforces stricter regulations compared to the USA, where companies have more freedom to experiment and deploy autonomous technologies.	Regulatory Framework & Safety	Regional Disparities

AV_E7	German	"In contrast, the EU's stricter framework creates a safer, more controlled environment. This ensures consistent minimum standards and helps build public trust, which is crucial for autonomous driving."	The EU's stricter regulations emphasize safety and build public trust by maintaining consistent minimum standards.	Regulatory Framework & Safety	Regional Disparities
AV_E9	German	"Standardization at the EU level would also be necessary for broader deployment across Europe."	EU-wide standardization is essential to enable consistent and widespread deployment of autonomous technologies across member states.	Regulatory Framework & Safety	Regional Disparities
AV_E9	German	"The U.S., particularly in states like California, has more flexible regulations, allowing for rapid testing and deployment of autonomous systems, though safety standards are still high."	The U.S., especially California, allows flexible regulations that support faster testing and deployment of autonomous systems while maintaining safety standards.	Regulatory Framework & Safety	Regional Disparities
AV_E9	German	"China is similarly progressive, with cities like Shenzhen and Beijing leading in pilot deployments."	China is proactive in automation, with cities like Shenzhen and Beijing spearheading pilot projects to advance autonomous systems.	Regulatory Framework & Safety	Regional Disparities
Reduction: Regional disparities in regulatory frameworks present significant challenges for the adoption of autonomous technologies. In Europe, stringent regulations emphasize safety but slow innovation, with fragmented national frameworks complicating cross-border scalability. Conversely, the U.S., with its flexible state-level self-certification models, accelerates deployment but raises concerns about uniform safety standards. China's centralized regulatory approach facilitates rapid implementation, leveraging urban testing zones to build public trust. These differing approaches highlight the need for harmonization to ensure balanced progress, allowing manufacturers to align safety, scalability, and public acceptance globally.					
AV_E1	German	"The regulatory framework for autonomous driving already has a foundation in Germany, particularly with the Level 4 Act and the related ordinance (AFGBV)."	Germany has established a foundational regulatory framework for autonomous driving, but further adaptations are needed to support broader adoption.	Regulatory Framework & Safety	Regulatory Basis
AV_E1	German	"Vehicles undergo rigorous testing and approval processes by entities such as the KBA to identify safety issues before deployment."	Regulatory approval processes like those by the KBA ensure potential safety issues are addressed before deployment.	Regulatory Framework & Safety	Regulatory Basis
AV_E3	English	"Strict regulatory standards and testing protocols will ensure that only thoroughly vetted systems are deployed, as seen in Europe's safety-first approach."	Rigorous testing and regulatory standards, like those in Europe, ensure autonomous systems are safe before commercialization.	Regulatory Framework & Safety	Regulatory Basis
AV_E8	German	Regulation isn't necessarily the main obstacle right now. Politicians are quite willing to pass laws or set up test tracks where autonomous driving can be tested."	The regulatory framework is not the main barrier to autonomous driving and is actively supporting advancements with test tracks and enabling laws.	Regulatory Framework & Safety	Regulatory Basis
AV_E8	German	"In Germany, we're relatively advanced in this area, even on an international scale."	Germany's regulatory environment for autonomous driving is advanced and supports testing and development compared to global standards.	Regulatory Framework & Safety	Regulatory Basis

AV_E9	German	"In Germany, for example, there's already legislation like the AFGBV that allows for the operation of Level 4 vehicles in defined domains."	Existing legislation, such as AFGBV in Germany, supports the operation of Level 4 vehicles within defined operational domains.	Regulatory Framework & Safety	Regulatory Basis

Reduction: Germany's regulatory framework for autonomous driving, including the AFGBV Level 4 Act and processes by entities like KBA, establishes a strong foundation for operational and safety standards. This system ensures rigorous testing before deployment and aligns with Europe's broader safety-focused approach. While regulation is advanced and supportive, adaptations are necessary to expand its applicability for broader deployment and scalability across different domains.

AV_E1	German	"Autonomous systems from Level 3 upwards require extensive approval processes, with all tests and test carriers registered with the KBA."	Stringent approval and testing processes for advanced autonomous systems increase regulatory burdens and slow down development.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E1	German	"Certain requirements in the current regulations seem impractical. For example, near-field communication must work within six meters of the vehicle."	Some regulatory requirements, such as near-field communication limits, are impractical and need adjustment for real-world applications.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E1	German	"Overcoming challenges in the regulatory and approval process, particularly at the state level in Germany, is a critical milestone."	Streamlining and harmonizing regulatory processes at the state and national levels is essential for scaling automation in Germany.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E2	German	"The regulatory framework for autonomous driving requires significant changes and adaptations to enable broader deployment and development."	Regulatory frameworks need significant updates to support the development and deployment of autonomous driving technologies.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E2	German	"Behavioral laws—governing how autonomous vehicles interact with human-driven vehicles, pedestrians, and other road users—need to be established and standardized."	Behavioral laws must be created and standardized to regulate interactions between autonomous and traditional road users.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E2	German	"Pilot programs and test zones must be expanded to inform better regulatory practices."	Expanding pilot programs and real-world testing zones is critical for improving regulatory frameworks.	Industry Readiness & Technology Advances	Regulatory Restrictions
AV_E2	German	"Regulations should reflect the highest safety standards while also being flexible enough to evolve as the technology matures."	Regulations must balance stringent safety standards with adaptability to keep pace with technological advancements.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E2	German	"Harmonization efforts, such as UNECE regulations expected by 2026, aim to create more uniform global standards."	Global harmonization efforts like UNECE regulations aim to address alignment challenges and create standardized frameworks by 2026.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E3	English	"Infrastructure regulations must account for upgrades to connectivity standards, such as moving beyond 5G to 6G for real-time communication."	Infrastructure and connectivity upgrades, like transitioning to 6G, are essential for enabling real-time vehicle communication and enhancing safety.	Industry Readiness & Technology Advances	Regulatory Restrictions

AV_E3	English	"Regulations need to address the coexistence of autonomous and human-driven vehicles, potentially with dedicated lanes for autonomous vehicles during the transition period."	Policies for managing mixed traffic conditions, such as introducing dedicated lanes for autonomous vehicles, can improve safety and operations.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E3	English	"Autonomous systems rely heavily on large amounts of data to train algorithms, but current data privacy laws can slow this process."	Balancing data privacy with the need for large-scale data use is critical to advancing autonomous vehicle technologies.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E3	English	"More extensive pilot programs and real-world testing are needed to provide insights into how autonomous vehicles interact with real-world conditions."	Real-world testing and pilot programs are invaluable for improving autonomous vehicle systems and transitioning from prototype to commercialization.	Industry Readiness & Technology Advances	Regulatory Restrictions
AV_E4	German	"For Level 4 and especially Level 5, we are still quite far from widespread adoption due to significant challenges like regulatory hurdles, system safety, and technical standards."	Levels 4 and 5 face major challenges, including regulatory, safety, and standardization issues, delaying widespread adoption.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E4	German	"The lack of harmonized standards creates uncertainty for manufacturers and hinders planning and development."	The absence of harmonized standards leads to uncertainty, complicating development and deployment of autonomous systems.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E4	German	"Regulations need to account for the validation and safety testing of autonomous systems, including robust frameworks for simulation and real-world scenario testing."	Safety testing frameworks for simulations and real-world scenarios are critical to validating autonomous systems.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E4	German	"For Levels 4 and 5, liability frameworks must clearly define that the manufacturer, not the passenger, is liable in the event of an accident."	Clear liability frameworks assigning responsibility to manufacturers for Levels 4 and 5 are needed to build public trust.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E4	German	"Regulations should focus on infrastructure readiness, ensuring that cities and road networks are equipped to support vehicle-to-infrastructure (V2I) communication."	Infrastructure regulations must ensure readiness for V2I communication to support the deployment of autonomous vehicles.	Industry Readiness & Technology Advances	Regulatory Restrictions
AV_E5	German	"Regulatory hurdles are another significant challenge, as regulations need to catch up with technological advances and remain dynamic as they evolve."	Keeping up with evolving national and international regulations is a critical challenge for the adoption of autonomous driving technologies.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E6	German	"And then there's the big question of liability—if there's an accident, who's responsible? Is it the manufacturer, the software provider, or the owner? That's a massive question that still needs answering."	Liability in autonomous vehicle accidents remains unresolved, with ambiguity over responsibility among manufacturers, software providers, and owners.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E6	German	"It's essential to establish standards for secure software updates and ensure that safety-critical systems	Regulations must address secure over-the-air updates and cybersecurity to protect	Regulatory Framework & Safety	Regulatory Restrictions

		are protected from cybersecurity threats."	safety-critical systems from external threats.		
AV_E6	German	"Additionally, regulations should focus on enabling testing in real-world environments. Autonomous systems rely on vast amounts of data to handle complex scenarios, and for that, we need more flexibility in how and where these systems can be tested safely and legally."	Real-world testing regulations should be more flexible to enable autonomous systems to gather the diverse data needed for handling complex scenarios safely and effectively.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E7	German	"These regulations should define the minimum safety and performance requirements for autonomous systems, creating a level playing field while ensuring public safety."	Regulations must establish minimum safety and performance benchmarks to ensure public safety and create a level playing field.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E7	German	"Second, the ethical considerations must be addressed transparently. Questions like how an autonomous vehicle should react in unavoidable accident scenarios need to be clearly outlined and regulated."	Ethical decision-making, particularly in accident scenarios, needs transparent and well-defined regulation to guide AI programming.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E7	German	"For example, there's the question of how an autonomous vehicle should behave in scenarios where an accident is unavoidable."	Ethical dilemmas in unavoidable accident scenarios pose significant challenges for autonomous vehicle safety.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E7	German	"Ensuring that the AI makes these decisions consistently and in a way that aligns with societal expectations is a huge challenge."	Aligning AI decision-making with societal norms and ensuring consistency is a critical operational challenge.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E8	German	"While regulation doesn't seem to be a primary barrier, liability is a critical unresolved issue. Questions about whether the responsibility lies with the system provider, the manufacturer, or the driver are still open and must be addressed, especially as we approach higher levels of automation."	Liability concerns, particularly regarding responsibility distribution among stakeholders, remain a critical barrier to advancing automation.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E8	German	"There are issues that need attention, like liability—figuring out whether the system provider, the manufacturer, or the driver is responsible in certain situations."	Liability remains a critical unresolved issue, requiring clarity on responsibility among system providers, manufacturers, and drivers.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E8	German	"Perhaps data protection is another area to consider, ensuring that privacy is maintained when everything is being tracked."	Data protection and privacy concerns need to be addressed as tracking becomes more prevalent in autonomous driving systems.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E9	German	"However, the framework needs to address scalability—extending these domains to broader regions or even cross-country operations."	Regulatory frameworks must evolve to support scalability, enabling Level 4 operations beyond localized areas to broader and cross-border regions.	Regulatory Framework & Safety	Regulatory Restrictions
AV_E9	German	"This requires collaboration between local authorities, regulatory bodies like the KBA and TÜV Süd, and policymakers to streamline approvals and provide clarity on operational design domains."	Effective collaboration among local authorities, regulatory bodies, and policymakers is necessary to streamline approvals and define operational design domains.	Regulatory Framework & Safety	Regulatory Restrictions

AV_E10	German	"Finally, there's regulation. We'll need advancements that make it possible to operate Level 4 systems across regions and even countries. That's a massive hurdle, but it's crucial for getting this technology out of its pilot phase and into everyday use."	Regulatory advancements are essential to enable the operation of Level 4 systems across regions and countries, a key step to move from pilot projects to widespread adoption.	Regulatory Framework & Safety	Regulatory Restrictions
Reduction: Regulatory restrictions pose critical barriers to autonomous system adoption, with challenges including stringent approval processes, liability concerns, and fragmented international standards. Germany's regulations, while advanced, require further adaptations to enable scalability, particularly for cross-border operations. Key issues include establishing clear liability frameworks for accidents, securing data privacy in real-world testing, and adapting testing requirements to accommodate rapid technological advancements. Additionally, balancing strict safety standards with flexibility for innovation is essential. Collaborative efforts among policymakers, manufacturers, and regulators are needed to harmonize standards, address liability, and support scalable deployment across diverse regions.					
AV_E1	German	"Automation promises to reduce accidents caused by human error, but it will not eliminate accidents entirely."	While automation can significantly reduce accidents caused by human error, it cannot achieve absolute safety perfection.	Public Perception & Trust in Automation	Safety & Risk Management
AV_E1	German	"There are also pockets of skepticism and concerns, particularly around safety and the ethical dilemmas posed by autonomous decision-making systems."	Concerns about safety and ethical decision-making pose significant challenges to public trust in automation.	Public Perception & Trust in Automation	Safety & Risk Management
AV_E2	German	"Safety will remain a key factor in public acceptance, with European regulation emphasizing the reliability of introduced vehicles."	Strong safety standards in Europe will build public trust in autonomous vehicles by ensuring reliability and minimizing risks.	Regulatory Framework & Safety	Safety & Risk Management
AV_E4	German	"Safety will be enabled through extensive simulation and real-world testing, using real-world data to train autonomous systems to handle more scenarios."	Simulation and real-world testing, combined with real-world data collection, are essential for improving system safety and handling complex scenarios.	Regulatory Framework & Safety	Safety & Risk Management
AV_E4	German	"People tend to focus heavily on safety, and there's a general skepticism about the readiness of the technology to handle complex, real-world situations."	Safety concerns and doubts about the readiness of autonomous systems to handle real-world complexities hinder public trust.	Public Perception & Trust in Automation	Safety & Risk Management
AV_E5	German	"There's a level of skepticism and fear regarding the safety and reliability of autonomous systems, and any mishaps can set back public confidence significantly."	Public skepticism about safety and reliability is a major challenge, as incidents can severely damage trust and hinder adoption.	Public Perception & Trust in Automation	Safety & Risk Management
AV_E6	German	"Public perception is a big hurdle—many people still have concerns about the safety of autonomous vehicles, and understandably so."	Public skepticism about the safety of autonomous vehicles is a significant challenge to adoption and trust.	Public Perception & Trust in Automation	Safety & Risk Management
AV_E6	German	"Safety will be enhanced through rigorous validation processes, where systems are tested extensively in controlled and simulated environments to ensure they can handle even the most unpredictable scenarios."	Rigorous testing in controlled and simulated environments is critical for ensuring that systems can manage unpredictable scenarios safely.	Regulatory Framework & Safety	Safety & Risk Management
AV_E6	German	"From my perspective, the most important factors for acceptance among the population are safety and reliability. People need to see that	Safety and reliability are the primary factors for public acceptance, especially the ability of	Public Perception & Trust in Automation	Safety & Risk Management

		autonomous systems can handle even rare and unpredictable scenarios safely."	autonomous systems to manage rare and unpredictable scenarios effectively.		
AV_E7	German	"The biggest challenges we face are, first, the safety and ethics aspect, and second, customer acceptance."	Key challenges for adopting autonomous driving include safety, ethical dilemmas, and customer trust and acceptance.	Industry Readiness & Technology Advances	Safety & Risk Management
AV_E8	German	"Safety is, of course, the top priority—people need to feel confident that autonomous systems are safer than human drivers. Transparent communication about how the vehicle operates, especially in the early stages, can help build that trust."	Demonstrating and communicating safety effectively is essential to building public trust in autonomous technologies.	Public Perception & Trust in Automation	Safety & Risk Management
Reduction: Safety concerns are a major factor in public acceptance of autonomous systems, with skepticism around their ability to handle unpredictable, real-world scenarios. Key challenges include demonstrating reliability through rigorous testing in both controlled and simulated environments to ensure systems perform effectively under diverse conditions. Public trust can be undermined by incidents, making transparency and communication about safety measures critical. European regulations emphasize reliability and safety validation to minimize risks and build confidence. Addressing these safety concerns, alongside ethical and customer trust issues, is fundamental to advancing adoption and ensuring the success of autonomous systems.					
AV_E1	German	"While some companies advocate for a single-camera approach, others rely on multi-sensor systems that, although more expensive, are considered more robust."	Diverse approaches to sensor systems reflect ongoing debates over cost versus reliability in autonomous technology design.	Industry Readiness & Technology Advances	Sensor Technology
AV_E2	German	"Sensor technology, while improving, still presents challenges, especially in terms of integration and redundancy."	Sensor integration and redundancy remain key challenges for ensuring reliable safety in autonomous systems.	Industry Readiness & Technology Advances	Sensor Technology
AV_E5	German	"Improving sensor technology and machine learning algorithms to enhance perception and decision-making capabilities is essential."	Advancements in sensor technology and machine learning algorithms are vital to improving the perception and decision-making capabilities of autonomous vehicles.	Industry Readiness & Technology Advances	Sensor Technology
Reduction: Advancements in sensor technology are critical for the reliability and safety of autonomous vehicles, with a focus on integration and redundancy to handle complex scenarios. Companies face trade-offs between cost-effective single-camera systems and multi-sensor setups that enhance robustness but increase expenses. Improving sensor accuracy and combining it with machine learning algorithms is essential to enhance perception and decision-making capabilities, addressing key challenges in autonomous vehicle technology design and deployment.					
AV_E2	German	"Collaborative opportunities with other industries exist but are somewhat limited by differences in operational needs and technological challenges."	Collaboration across industries is possible but constrained by differing operational and technological requirements.	Comparative Analysis	Synergy Effects
AV_E2	German	"In urban air mobility, drones have been flying autonomously, showing that autonomous operation in three-dimensional airspace is easier than navigating crowded streets."	Urban air mobility demonstrates the relative simplicity of autonomous operation in airspace compared to the complexities of road navigation.	Comparative Analysis	Synergy Effects
AV_E2	German	"The two industries share some technological parallels, such as IT infrastructure and algorithms, but their specific requirements limit direct collaboration."	Technological overlaps, like IT infrastructure and algorithms, offer some potential for collaboration, though unique requirements pose challenges.	Comparative Analysis	Synergy Effects

AV_E2	German	"Mobility providers could develop integrated transportation packages combining autonomous vehicles and air mobility solutions for seamless customer experiences."	Integrated transportation packages combining autonomous vehicles and air mobility could create seamless, multi-modal solutions for customers.	Comparative Analysis	Synergy Effects
AV_E2	German	"Collaboration in technological development might be limited, but industries can align on infrastructure planning and policy advocacy to promote automation-friendly environments."	While technological collaboration is limited, industries can work together on infrastructure planning and policy advocacy to support automation.	Comparative Analysis	Synergy Effects
AV_E3	English	"One key area of collaboration is with the telecommunications industry, as autonomous driving relies heavily on advanced connectivity for V2V and V2I communication."	Collaboration with telecom providers to expand high-speed networks like 5G and 6G is essential for enabling real-time communication in autonomous systems.	Comparative Analysis	Synergy Effects
AV_E4	German	"Technologies used in autonomous flight, such as advanced sensors and navigation algorithms, could be adapted for road-based vehicles."	Innovations in aviation, like sensors and navigation algorithms, have potential applications for autonomous road vehicles.	Comparative Analysis	Synergy Effects
AV_E4	German	"The aviation industry operates in a much more controlled environment with specific airspace regulations, which is different from challenges faced by autonomous vehicles on roads."	Differences in operational contexts, such as controlled airspace versus unpredictable road conditions, limit the direct applicability of aviation solutions.	Comparative Analysis	Synergy Effects
AV_E4	German	"While there's potential for knowledge transfer, the different operational contexts mean that not all solutions are directly transferable."	Knowledge transfer between industries is valuable but constrained by differences in their operational environments and challenges.	Comparative Analysis	Synergy Effects
AV_E5	German	"Many of the methodologies we use in the development of autonomous systems come from the aviation industry. The aerospace sector has long been a pioneer in creating redundant systems and ensuring functional safety, and we've adopted similar principles."	The automotive industry has leveraged methodologies and best practices from aviation, particularly in areas like redundancy and safety, to enhance automation development.	Comparative Analysis	Synergy Effects
AV_E5	German	"Collaboration with industries involved in infrastructure development is also crucial. Vehicle-to-infrastructure (V2I) communication will play a major role in the success of autonomous vehicles."	Partnerships with infrastructure and telecommunications industries are critical for enabling V2I communication and ensuring seamless operation of autonomous vehicles.	Comparative Analysis	Synergy Effects
AV_E6	German	"For instance, we can learn a lot from the aerospace industry, particularly in areas like simulation-based testing and dealing with edge cases."	The aerospace industry provides valuable insights into simulation-based testing and managing edge cases, which can benefit autonomous vehicle development.	Comparative Analysis	Synergy Effects
AV_E6	German	"Aviation has long used assistance systems, like autopilot, which share	The use of autopilot in aviation demonstrates	Comparative Analysis	Synergy Effects

		methodological similarities with autonomous vehicle systems."	methodological similarities that could inform autonomous vehicle systems.		
AV_E6	German	"There's also potential synergy with the tech industry, especially in developing AI, machine learning, and sensor technologies."	Collaboration with the tech industry could enhance AI, machine learning, and sensor technologies critical for autonomous systems.	Comparative Analysis	Synergy Effects
AV_E7	German	"These industries could share insights and developments that benefit autonomous driving, particularly in areas like LIDAR technology or real-time decision-making algorithms."	Cross-industry knowledge transfer can accelerate advancements in shared technologies like LIDAR and decision-making AI systems.	Comparative Analysis	Synergy Effects
AV_E7	German	"However, the requirements between industries can differ significantly. In aviation, factors like pressure, weather conditions, and air traffic are far more critical than the environmental and traffic considerations in autonomous driving."	Differences in operational environments and requirements can limit the applicability of certain technologies between industries.	Comparative Analysis	Synergy Effects
AV_E7	German	"On the service side, there's potential for synergies, such as integrating autonomous ground transportation with aviation."	Collaborations between industries can enhance service integration, such as combining robo-taxi systems with air travel for seamless mobility.	Comparative Analysis	Synergy Effects
AV_E7	German	"For instance, airlines could partner with robo-taxi providers to create seamless mobility services for passengers, offering door-to-door solutions from the airport to their final destinations."	Partnerships between airlines and autonomous vehicle providers could create integrated transportation services, boosting public acceptance.	Comparative Analysis	Synergy Effects
AV_E8	German	"There's potential to learn from aviation's approaches to safety validation, redundancy, and human-machine interaction, particularly when it comes to building trust with passengers."	Lessons from aviation in safety validation, redundancy, and human-machine interaction can help improve trust in autonomous systems in other industries.	Comparative Analysis	Synergy Effects
AV_E8	German	"Integrating autonomous vehicles with drones for delivery services could open up new mobility solutions and help refine both technologies."	Collaboration between autonomous vehicles and drones for delivery services could lead to innovative mobility solutions and technological improvements.	Comparative Analysis	Synergy Effects
AV_E11	German	"The safety standards in aviation, for instance, could provide valuable insights for redundancy and reliability in system architectures."	Aviation's rigorous safety standards can guide the development of redundancy and reliability measures in autonomous systems.	Comparative Analysis	Synergy Effects
AV_E12	German	"There's also potential for collaboration on the regulatory front, where different industries could learn from each other's frameworks to accelerate adoption."	Cross-industry collaboration on regulatory frameworks could streamline processes and accelerate the adoption of automation technologies.	Comparative Analysis	Synergy Effects

Reduction: Synergy effects between industries, such as automotive, aviation, and urban air mobility, offer potential for advancing autonomous technologies and mobility solutions. Aviation's expertise in redundancy and safety provides valuable insights for autonomous vehicle development, while urban air mobility highlights streamlined automation in controlled environments. These insights can create an integrated mobility service solution, such as combining autonomous vehicles and urban air systems to create seamless, multimodal transport experiences. Knowledge sharing in areas like AI, sensor technologies, and decision-making algorithms can further accelerate innovation. Despite challenges from operational and regulatory differences, cross-industry collaboration remains essential for fostering scalable automation and future-ready mobility systems.					
AV_E5	German	"Redundancy is crucial, with multiple systems in place to take over if one fails, ensuring operational safety in emergencies."	Redundancy through backup systems is critical to maintaining safety and operational functionality during failures.	Industry Readiness & Technology Advances	System Redundancy
AV_E6	German	"To enable safety with increased automation, redundancy is key. This involves combining multiple sensor types—cameras, radar, and LiDAR—to ensure that when one type is impaired (e.g., a camera in heavy rain), the others can compensate."	Redundancy through the use of multiple sensor types ensures operational safety by compensating for impairments under adverse conditions.	Industry Readiness & Technology Advances	System Redundancy
AV_E8	German	"Features like advanced sensors, redundant systems, and fallback protocols are essential to ensure that the vehicle can navigate safely even when one component fails."	Advanced sensors, redundancy, and fallback protocols are critical for maintaining safety despite component failures.	Regulatory Framework & Safety	System Redundancy
AV_E9	German	"Safety largely hinges on system architecture. Redundancy is critical ensuring that failures in one component, such as sensors or brakes, don't compromise the entire system."	System architecture and redundancy are essential for safety, ensuring failures in individual components don't compromise the entire system.	Regulatory Framework & Safety	System Redundancy
Reduction: System redundancy is vital for ensuring operational safety and reliability in autonomous systems. Redundant architectures, such as employing multiple sensor types (cameras, radar, and lidar), provide fail-safes that maintain functionality under adverse conditions or component failures. Advanced systems with backup protocols ensure that critical operations are not compromised, even in emergencies. This redundancy framework supports safety and reliability, reinforcing the resilience of autonomous vehicles against unexpected challenges and technical malfunctions.					
AV_E1	German	"On the technological front, although Level 4 systems are technologically mature in many ways, certain areas, such as safety in extreme weather conditions, edge cases, and system integration..."	Refining safety in extreme conditions and system-wide integration remains a key technological challenge for Level 4 systems.	Industry Readiness & Technology Advances	Technological Limitations
AV_E1	German	"Prediction and decision-making algorithms must interpret environments accurately and adapt to new scenarios."	Advanced prediction and decision-making algorithms are essential for interpreting and adapting to changing environments safely.	Industry Readiness & Technology Advances	Technological Limitations
AV_E1	German	"The next significant milestones for automation in the automotive industry include achieving functional deployment of Level 4 systems and scaling their use in specific applications."	Deployment and scaling of Level 4 autonomous systems in targeted applications represent key milestones for the industry's progress.	Industry Readiness & Technology Advances	Technological Limitations
AV_E2	German	"Ensuring reliability and safety across all driving conditions, including adverse weather, remains a major hurdle."	Achieving reliability and safety in adverse and unpredictable conditions is a significant technological challenge.	Regulatory Framework & Safety	Technological Limitations
AV_E2	German	"The primary safety concerns include handling complex and unpredictable real-world scenarios, particularly under adverse weather conditions."	Safety concerns focus on the ability of autonomous systems to handle unpredictable scenarios and adverse weather conditions.	Regulatory Framework & Safety	Technological Limitations

AV_E3	English	"Full autonomy, as defined by SAE Level 5, is still years away and faces significant technical, regulatory, and public acceptance challenges."	Achieving full autonomy (Level 5) is distant and constrained by technological, regulatory, and societal barriers.	Future Outlook & Strategic Vision	Technological Limitations
AV_E3	English	"One of the biggest hurdles is the computing power required for these systems, as training and deploying models can take weeks or months due to computational complexity."	The high computational demands for training and deploying autonomous systems slow progress in automation development.	Industry Readiness & Technology Advances	Technological Limitations
AV_E3	English	"Advancements in chips, like Nvidia's recent offerings, are improving processing speeds, but hardware development still lags behind rapid software evolution."	Hardware advancements, while progressing, are not keeping pace with software innovation, creating a bottleneck in automation technologies.	Industry Readiness & Technology Advances	Technological Limitations
AV_E4	German	"Redundant systems will be critical to ensure that backup sensors and algorithms are in place in case of a failure."	Redundancy in sensors and algorithms is vital to maintaining safety in the event of system failures.	Industry Readiness & Technology Advances	Technological Limitations
AV_E4	German	"Advanced algorithms that learn and adapt from vast datasets will improve the ability of autonomous systems to handle complex situations safely."	Advanced, adaptive algorithms trained on large datasets are crucial for enhancing the capability of autonomous systems to navigate complex scenarios.	Industry Readiness & Technology Advances	Technological Limitations
AV_E4	German	"Reliability also plays a crucial role. The technology must be able to consistently perform in a wide variety of conditions."	Consistent and reliable performance across diverse conditions is essential for fostering confidence in autonomous systems.	Industry Readiness & Technology Advances	Technological Limitations
AV_E5	German	"The technology behind autonomous driving, particularly at levels 4 and 5, is currently at a stage where operational and commercial use remains a considerable challenge."	Levels 4 and 5 autonomous driving face significant technological challenges before achieving operational and commercial viability.	Industry Readiness & Technology Advances	Technological Limitations
AV_E5	German	"Even Level 4, which allows for high autonomy within specific operational design domains, presents significant hurdles in ensuring safety and reliability."	Level 4 autonomy faces hurdles in ensuring safety and reliability within defined operational domains, delaying its commercial readiness.	Industry Readiness & Technology Advances	Technological Limitations
AV_E5	German	"The primary safety concerns revolve around ensuring that autonomous systems can handle all driving scenarios without human intervention, including real-time decisions in complex environments."	Autonomous systems must reliably manage real-time decisions in complex environments, emphasizing the need for comprehensive operational safety.	Regulatory Framework & Safety	Technological Limitations
AV_E7	German	"At this level, vehicles can manage certain driving tasks on highways, allowing the driver to let go of the steering wheel for limited periods, though regular intervention is still required."	Level 3 systems allow partial autonomy for highway driving, requiring occasional driver intervention.	Industry Readiness & Technology Advances	Technological Limitations
AV_E7	German	"From my perspective, the scalability of these technologies is not yet achieved, and it will take more time to overcome challenges related to	Scalability of autonomous driving technologies faces challenges in technical advancement and	Public Perception & Trust in Automation	Technological Limitations

		both technology and customer acceptance."	customer acceptance, requiring more time to mature.		
AV_E7	German	"The primary safety concerns with increased automation revolve around the reliability of the technology and how it responds to complex, unpredictable situations."	Reliability and response to unpredictable scenarios are major safety concerns in autonomous driving technology.	Regulatory Framework & Safety	Technological Limitations
AV_E7	German	"Next, the technology must become ready for series production. Right now, Level 4 and 5 automation is mostly in the prototype stage, and scaling it for commercial use is a critical step."	Transitioning Level 4 and 5 automations from prototypes to scalable commercial products is a key milestone.	Industry Readiness & Technology Advances	Technological Limitations
AV_E8	German	"The technology behind autonomous driving has made notable progress, but it's not yet ready for widespread operational or commercial use, especially at Level 5."	Autonomous driving technology has advanced significantly but remains far from being commercially viable at Level 5.	Industry Readiness & Technology Advances	Technological Limitations
AV_E8	German	"Even for Level 4, while we're seeing proof-of-concept implementations and some advancements in premium vehicles, these are still years away from mass adoption."	Level 4 technologies are being developed and tested in premium vehicles but are not yet ready for widespread adoption.	Industry Readiness & Technology Advances	Technological Limitations
AV_E8	German	"Technology is lagging behind regulation, not the other way around. The focus should be on advancing the technical development."	Technological advancements in autonomous driving are currently slower than regulatory developments, which are relatively progressive.	Industry Readiness & Technology Advances	Technological Limitations
AV_E8	German	"To enable safety as automation increases, companies are focusing on comprehensive validation methods and data-driven approaches."	Safety is enabled by comprehensive validation methods and leveraging data-driven technologies to train systems for diverse scenarios.	Industry Readiness & Technology Advances	Technological Limitations
AV_E9	German	"But the readiness is limited to these specific zones. Outside of these geofenced areas, the technology still faces significant challenges."	The scalability of Level 4 autonomy is limited by its reliance on geofencing, making it operational only in specific, pre-mapped environments.	Industry Readiness & Technology Advances	Technological Limitations
AV_E9	German	"These systems rely heavily on high-resolution sensors, pre-mapped environments, and specific conditions. This makes them less flexible and not easily scalable to new regions."	Level 4 systems depend on advanced sensors, pre-mapped zones, and controlled conditions, which limit their adaptability and scalability to new or dynamic regions.	Industry Readiness & Technology Advances	Technological Limitations
AV_E9	German	In some cases, if a vehicle encounters an unexpected situation—like construction or a blocked road—remote operators step in to assist. While this helps maintain operations, it highlights that the technology still needs human backup, which limits its true autonomy."	The reliance on teleoperation for managing unexpected situations reveals the current limitations of autonomous systems in achieving full independence.	Industry Readiness & Technology Advances	Technological Limitations
AV_E9	German	"So, to sum it up: Level 4 is 'ready' for operational use in specific scenarios—where the environment is controlled, the technology is supported, and the costs are	Level 4 autonomy is operational in specific use cases but faces challenges in scaling to unrestricted,	Industry Readiness & Technology Advances	Technological Limitations

		justifiable. But for broader, unrestricted commercial use, there's still a lot of ground to cover, especially in scaling, adaptability, and cost-effectiveness."	commercial environments due to limitations in adaptability, cost, and operational infrastructure.		
AV_E9	German	"Today's AI models work well in normal conditions but struggle with outliers and solving these requires advancements in AI and machine learning."	Current AI models perform reliably under normal conditions but require improvements to handle outlier scenarios effectively.	Industry Readiness & Technology Advances	Technological Limitations
AV_E9	German	"Another big milestone is scaling these systems beyond their current geofenced zones. Right now, Level 4 works in very controlled environments, like small sections of cities that have been extensively mapped and tested. The real challenge is making these systems adaptable so they can operate in new environments without needing months of preparation."	Scaling Level 4 systems beyond geofenced zones is essential for broader deployment, requiring adaptability to operate in varied environments without extensive preparation.	Industry Readiness & Technology Advances	Technological Limitations
Reduction: Technological limitations remain a significant hurdle for advancing autonomous driving. Key challenges include ensuring reliability in extreme weather conditions, addressing edge cases, and integrating systems to maintain safety and consistency. Current Level 4 autonomy is operational in geofenced areas but struggles with scalability, adaptability, and cost in broader and unpredictable environments. The reliance on pre-mapped data, advanced sensors, and teleoperations highlights gaps in achieving full independence. Comprehensive validation, leveraging adaptive algorithms, and improving system redundancy are essential to overcoming these limitations and progressing toward scalable, reliable autonomous driving solutions.					
AV_E1	German	"The technology for autonomous driving is making significant progress, particularly at Level 4, but there are still considerable challenges before it can be operational or commercial..."	Level 4 automation is advancing but faces challenges in broad deployment, while Level 5 remains a long-term vision. Infrastructure and environmental factors are major hurdles.	Industry Readiness & Technology Advances	Technological Progress
AV_E1	German	"From a technological standpoint, many key components necessary for Level 4 systems are already in place and well-developed."	Key technologies for Level 4 systems, such as sensors and computing, are well-developed, signifying significant technological progress.	Industry Readiness & Technology Advances	Technological Progress
AV_E1	German	"Today's vehicles operate with vast amounts of software—up to 150 million lines of code—demonstrating the technological complexity and capability already achieved."	Modern vehicles reflect substantial software integration, highlighting the complexity and capability of current technology.	Industry Readiness & Technology Advances	Technological Progress
AV_E3	English	"Autonomous driving technology is operational and commercially available at certain levels, such as Mercedes-Benz's Level 3 systems in California, Texas, and Germany."	Level 3 autonomous systems are commercially viable and operational, with limited deployment in high-end vehicles and specific regions.	Industry Readiness & Technology Advances	Technological Progress
AV_E3	English	"These systems are available in high-end models like the S-Class and GLS, enabling hands-free driving up to 60 km/h in urban areas and 90 km/h on highways."	Current Level 3 systems are functional but restricted to premium vehicles and specific speed and use-case limitations.	Industry Readiness & Technology Advances	Technological Progress
AV_E3	English	"Redundancy in systems, such as multiple layers of sensors and backup components, will be critical to maintaining operational safety."	Redundant systems ensure safety by allowing autonomous vehicles to continue functioning even if a component fails.	Regulatory Framework & Safety	Technological Progress

AV_E3	English	"Cloud-based updates and data sharing will enable vehicles to learn collectively by analyzing unusual situations and retraining systems."	Cloud-based data sharing and updates allow autonomous systems to continuously improve by learning from collective experiences.	Industry Readiness & Technology Advances	Technological Progress
AV_E3	English	"Connectivity infrastructure will enhance safety by enabling real-time communication between vehicles and traffic infrastructure."	Advanced connectivity enables real-time vehicle-to-vehicle and vehicle-to-infrastructure communication, reducing accident risks.	Industry Readiness & Technology Advances	Technological Progress
AV_E5	German	"The first major shift is towards virtualization and the use of advanced simulation technologies to simulate millions of driving scenarios digitally."	The future workforce must develop skills in virtualization and advanced simulation technologies to address the complexities of real-world testing.	Industry Readiness & Technology Advances	Technological Progress
AV_E5	German	"Another critical milestone is advancing the technical capabilities of autonomous systems, including improving sensor technology, software algorithms, and vehicle-to-infrastructure (V2I) communication."	Enhancing sensor technologies, software, and V2I communication is critical for reliable and efficient autonomous system functionality.	Industry Readiness & Technology Advances	Technological Progress
AV_E6	German	"For Level 4, where the vehicle operates independently within a restricted operational domain, the technology is advancing and is already being tested and implemented in controlled environments, such as Waymo vehicles operating in specific areas in the U.S."	Level 4 autonomous technology is advancing and being tested in controlled environments but remains restricted to specific operational domains.	Industry Readiness & Technology Advances	Technological Progress
AV_E6	German	"This involves improving sensor technology, creating robust predictive models for understanding the behavior of other road users, and using simulation-based testing to validate systems."	Achieving safety and reliability requires advancements in sensor technology, predictive modeling, and rigorous simulation testing to validate autonomous systems.	Industry Readiness & Technology Advances	Technological Progress
AV_E7	German	"Currently, we see more advancements at Level 3, particularly in German-speaking countries, with companies like Mercedes-Benz pioneering in this area."	Level 3 autonomy is advancing, with notable progress by companies like Mercedes-Benz, particularly in German-speaking regions.	Industry Readiness & Technology Advances	Technological Progress
AV_E9	German	"If you look at the current state of Level 4 technology, you could say it’s ready—and at the same time, it isn’t. On one hand, we already have Level 4 systems in operation. For example, you can order a fully autonomous ride in parts of San Francisco or Phoenix using Waymo services."	Level 4 technology is operational in controlled, geofenced areas where the environment and infrastructure support its functionality.	Industry Readiness & Technology Advances	Technological Progress
AV_E9	German	"In China, too, companies are deploying similar systems in cities like Shenzhen and Beijing. So, in these controlled, localized environments, the technology is operational and commercially viable to a certain extent."	Controlled, localized deployments of autonomous systems are commercially viable in select cities globally, such as Shenzhen, Beijing, San Francisco, and Phoenix.	Industry Readiness & Technology Advances	Technological Progress

Reduction: Autonomous driving technology has made significant progress, with Level 3 systems in premium vehicles and Level 4 operational in controlled, geofenced areas. Advancements in sensors, software integration, redundancy, and vehicle-to-infrastructure connectivity are driving the industry forward. Testing and data-driven learning play a vital role in refining these systems. However, challenges persist in scaling the technology to broader environments, reducing costs for commercialization, and ensuring functionality in

diverse conditions such as extreme weather or variable infrastructure. Addressing these issues is essential for widespread deployment and adoption.

A.3.1.2 SiPO Experts

Expert Number	Interview Language	Paraphrase	Generalization	Category	Code
SiPO_E1	German	"We are at the very beginning, I would say, we are just starting to understand what this concept means."	The concept is at its early stages with many challenges ahead.	Industry Readiness & Technology Advances	Development Stage
SiPO_E2	English	"According to Airbus, SiPO and eMCO ops are feasible today. EASA provides a timeline that's approximately 3 years in the future."	Airbus and EASA assume that the concept is already technologically feasible.	Industry Readiness & Technology Advances	Development Stage
SiPO_E5	English	"The first steps are development and test flights. That is what is already happening."	Initial steps like development and test flights are underway.	Public Perception & Trust in Automation	Development Stage
SiPO_E5	English	"To show a track record there are many steps in between."	Establishing a safety track record requires a multi-step, long-term process.	Public Perception & Trust in Automation	Development Stage
Reduction: The development of single pilot operations is still in its early stages and there are still significant hurdles to overcome. While Airbus already considers the technology to be feasible and EASA outlines a preliminary timeframe of three years, these forecasts only underscore the potential, not the readiness for implementation. Initial steps, such as development and test flights, provide a foundation, but creating a comprehensive safety case requires a multi-stage, long-term effort. This shows a clear gap between technological capability and operational reality. A successful introduction will depend on safety and reliability being demonstrated over an extended period, which makes it clear that widespread acceptance is still a long way off.					
SiPO_E1	German	"The biggest obstacles to the concept are currently costs."	Costs play a major role in the implementation of SiPO.	Industry Readiness & Technology Advances	Economic Drivers & Challenges
SiPO_E1	German	"That's a bit of the reason why we don't yet have self-driving trains, for example."	The absence of autonomous trains casts doubts on the economic reasoning	Industry Readiness & Technology Advances	Economic Drivers & Challenges
SiPO_E1	German	"The additional effort that has to be made to save this one person is extremely high and the question at the end of the day is 'what does the additional effort cost and what does the pilot cost?'"	The cost and effort of technical systems versus human pilots is a critical consideration.	Industry Readiness & Technology Advances	Economic Drivers & Challenges
SiPO_E1	German	"There are many technical systems that we will need. The question then is what these technical systems will cost as opposed to the human being."	The cost and necessity of technical systems are central to evaluating feasibility.	Industry Readiness & Technology Advances	Economic Drivers & Challenges
SiPO_E1	German	"Is this need really there in the market? […] It is possible that at some point... we say that it is technically possible but not economically interesting."	The market demand for single-pilot operations must be assessed before large-scale implementation.	Future Outlook & Strategic Vision	Economic Drivers & Challenges
SiPO_E1	German	"It is also possible that at some point in the further development we will reach a point where we say that it is technically possible but not economically interesting."	Technological feasibility does not mean that SiPO will necessarily be implemented, as there might not be an economic benefit in the end.	Future Outlook & Strategic Vision	Economic Drivers & Challenges
SiPO_E3	English	"The primary motive for SiPO/eMCO is profit for corporations and lower ticket prices for customers."	Profit and cost savings are the main drivers behind SiPO/eMCO implementation, raising questions about safety priorities.	Future Outlook & Strategic Vision	Economic Drivers & Challenges

SiPO_E3	English	"At the moment, from a financial risk standpoint, I think that the possibility of SiPO/eMCO being seriously considered is far in the future. The return on investment is very small and the risk is high."	The financial risks associated with SiPO/eMCO make its serious consideration unlikely in the near future.	Industry Readiness & Technology Advances	Economic Drivers & Challenges
SiPO_E3	English	"One reason why SPO is being considered is that during most of the flight, the pilots have an extremely low workload. […] Airlines see this time as wasted profits."	SPO is being considered because pilots have minimal workload during most of the flight, which airlines view as an opportunity to reduce costs and increase profits.	Industry Readiness & Technology Advances	Economic Drivers & Challenges
SiPO_E3	English	"The most significant challenge is the liability factor. [...] The cost of having two full-time pilots could be seen as a cost-effective alternative to a crash (lawsuits and reputation). This is a huge risk with little return on investment. I don't see any airline or airframer taking the risk. "	Liability and financial risk are key barriers, with the potential costs of a crash outweighing savings from reduced crews.	Industry Readiness & Technology Advances	Economic Drivers & Challenges
Reduction: The implementation of SiPO depends on cost considerations, both in terms of operational savings and financial risks. Airlines are profit-oriented and consider the low utilization of pilots on long-haul flights to be inefficient. Two crew members, especially on long-haul flights where pilots have a very low workload is seen as "wasted profits", and the reduction of crew members therefore potential savings. However, this strategy faces significant obstacles. The cost of developing and implementing the necessary technical systems compared to maintaining human pilots remains a deciding factor. The effort that has to be made to reduce the cockpit crew by one person is incredibly high, raising the question if SiPO even has a compelling economic justification.					
SiPO_E1	German	"I am very sure that this will be done in the cargo sector first."	Initial implementation of single-pilot operations will likely occur in the cargo sector.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E1	German	"I think it will also be single-pilot and cruise first... then one person will actually go to sleep in cruise flight."	SiPO will start with eMCO as predecessor	Future Outlook & Strategic Vision	Future Outlook
SiPO_E1	German	The Asian market is exciting because the growth there is significantly greater... they don't have enough pilots."	Pilot shortages in rapidly growing markets like Asia may accelerate adoption of single-pilot concepts.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E1	German	"I can imagine that it will happen for the cargo sector within the next 10 or 15 years."	Implementation of SiPO is likely to begin in the cargo sector within 10-15 years, starting with eMCO configurations.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E1	German	"I find it hard to imagine that we will be able to carry out entire large flights with just one person in American and European airspace."	Single-pilot operations for passenger flights face significant geographic and safety barriers in densely populated areas.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E1	German	"I am very divided on this. Fifty-fifty, so I wouldn't necessarily say that's coming."	It is definitely possible that SiPO will never be implemented.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E2	English	"To be honest, long after I retire (I'll retire in 3 years). SiPO may never happen."	There is skepticism about SiPO implementation, with predictions extending far into the future, possibly never happening.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E2	English	"eMCO within a very tight framework could be acceptable in ~5 years."	eMCO might be achievable in a tightly regulated framework within approximately five years.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E2	English	"I personally would think that eMCO in cargo operations would lead to adoption/acceptance of eMCO in	The adoption of eMCO in cargo operations is expected to pave the way for passenger	Future Outlook & Strategic Vision	Future Outlook

		passenger ops and eventually SiPO in cargo, then pax."	operations and eventually SiPO in cargo and passenger sectors.		
SiPO_E2	English	"Demonstrated periods of safe ops would begin to provide data to change the current system."	Extended periods of safe operations are crucial to collecting data that can drive systemic changes and wider acceptance.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E3	English	"The field is ripe in General Aviation. We could make such progress there. […] If we can make the single-pilot GA safety record close to the commercial record [...] they might come to expect it on their jets."	Enhancing single-pilot safety in general aviation could influence expectations for commercial aviation designs.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E3	English	"The milestone that must be hit to achieve SiPO/eMCO is to either build automation that has adaptability and big-picture awareness and/or involve the human."	Achieving SiPO/eMCO requires adaptable automation or effective human-automation collaboration.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E5	English	"it is going to take many years until we will see SiPO in commercial aircraft."	Even though technologically advanced, the concept will take many years to be commercially implemented.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E5	English	"It will come at some point."	Regulations will at be adapted, even though it may be far in the future.	Regulatory Framwork & Safety	Future Outlook
SiPO_E5	English	"I think when we are talking about commercial aviation we are talking about many years."	Regulations adaption for commercial air transport will happen in the further future.	Regulatory Framwork & Safety	Future Outlook
SiPO_E5	English	"a track record is needed"	Trial phases are needed to convince regulators to adapt regulations for commercial flights.	Regulatory Framwork & Safety	Future Outlook
SiPO_E5	English	"I think the only way to develop a track record is through cargo transport. […] If that works well, I can see commercial aviation follow up pretty soon, at least for more regional flights."	Cargo is likely to serve as a predecessor of SiPO in commercial aviation.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E5	English	"For cargo transport, I can imagine that regulations will be adapted within the next 10 years."	Regulations for cargo transport might be adapted within the next 10 years.	Regulatory Framwork & Safety	Future Outlook
SiPO_E5	English	"Cargo flights will serve as the testing ground. I believe first operational trials could start within the next couple of years and broader implementation in the 2030s, as they present fewer risks on human lives."	Cargo flights are expected to be the initial testing phase for SiPO, with trials starting soon and broader use expected in the 2030s.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E5	English	"Regulatory bodies will start seriously considering new standards in the 2030s as well (for passenger transport)."	Regulatory progress for passenger SiPO flights is likely to gain momentum in the 2030s.	Future Outlook & Strategic Vision	Future Outlook
SiPO_E5	English	"The EASA is currently conducting risk assessments; the FAA is more reluctant."	EASA is actively assessing risks, while the FAA adopts a more cautious approach to regulatory changes.	Future Outlook & Strategic Vision	Future Outlook

Reduction: The implementation of SiPO concept is expected to begin with cargo operations, where the risks to human life are lower and therefore provide a suitable testing ground. Initial testing could begin in a few years, with broader adoption planned for the 2030s. eMCO configurations, in which a single pilot operates the aircraft during the cruising phase, will likely serve as a precursor to full SiPO implementation. These configurations could be realizable within five years under a strict regulatory framework.

Regions such as Asia, which are facing a shortage of pilots due to rapid growth, could accelerate the introduction of single-pilot concepts. However, in densely populated areas such as North America and Europe, significant geographical and safety challenges remain, making widespread introduction in passenger transport difficult.

A proven track record in cargo operations will be crucial to gaining regulatory approval and public trust. Proven success in general aviation could further influence expectations and drive systemic change in commercial aviation. While EASA conducts risk assessments, the FAA remains more cautious. While some experts are optimistic that the regulations will eventually be adapted, others remain skeptical because the time frames extend far into the future or the implementation as a whole is being questioned.					
SiPO_E1	German	"A single pilot is a different type of person, so it has to be someone who is very happy to work alone and who has to make decisions on their own."	The role of a pilot in this concept is very different.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E1	German	"What happens when this person flies over the Atlantic in the dark for 10 hours at night? [...] On the human-psychological side, there are still a lot of unanswered questions. [...] The psychological area is much bigger than you might think."	Psychological and behavioral readiness for single pilots remains an area of uncertainty.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E1	German	"How will this person be educated and trained? How can they gain experience?"	Specialized training and experience frameworks for single pilots are necessary for readiness.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E1	German	"Will it be an obstacle in the end? I don't know. It is certainly a cost factor."	Human factors of SiPO implementation will be costly.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E2	English	"Pilots seem to be adaptable to new technologies to include automation. The trick is the man/machine interface."	Pilots are adaptable to automation (can be trained), but the challenge lies in improving the human-machine interface.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E2	English	"Do automated systems on aircraft (SiPO/eMCO) reduce the total employment count or will others take on new roles such as systems and health monitors?"	Increased automation may lead to a shift in workforce roles rather than reducing overall employment numbers.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E3	English	"There are still some technical and human factors barriers to operations in abnormal and unexpected situations. [...] The human in the cockpit will still have the extra task of working with that automation."	Technical and human factors during abnormal situations remain a significant barrier for SiPO/eMCO.	Industry Readiness & Technology Advances	Human Factors and Skills
SiPO_E3	English	"I do not believe that new skills or competencies will be required. Rather, the problem is skill loss. Programming automation and then watching it perform perfectly day after day causes aviate/navigate/communicate/manage-tasks skills to atrophy."	The challenge is not learning new skills but preventing the loss of existing ones.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E3	English	"Automation is actually handicapping the human when the human needs the most help."	Over-reliance on automation can hinder human performance during critical moments, creating safety risks.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E4	English	"High initial investments in technology and retraining the workforce."	High costs of technology and workforce retraining are significant adoption barriers.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E4	English	"Future professionals must have advanced technical knowledge of automated systems, strong problem-solving abilities, and training in emergency manual override procedures."	Advanced technical knowledge and problem-solving skills are essential for managing automation.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E4	English	"Reducing cockpit crew diminishes the collaborative problem-solving dynamic critical to managing unexpected challenges."	Reduced cockpit crews limit collaborative problem-solving during critical situations.	Impact on Human Roles & Employment	Human Factors and Skills

SiPO_E4	English	"Human error during automation handoffs."	Automation handoffs are prone to human error.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E5	English	"First of all, the pilot of course [...] airlines will have to hire a different type of person for a pilot. Less teamwork, more individual decision-making, more independence and responsibility."	SiPO would require a different type of person as a pilot, there would be a major change in the workforce.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E5	English	"The requirements in terms of technological understanding will be different. A single pilot needs to understand what the autonomous system is doing at all times, understand when and how to intervene and at the same time keep his manual flying skills, which can be very difficult when the time of manually flying is further reduced."	Pilots will also need different skills and trainings.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E5	English	"And then of course ATC will need completely new training, they might have to communicate with a pilot who is at the same time actively flying the aircraft."	SiPO would require new training and skills in ATC (air traffic control) as well.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E5	English	"There will be different procedures and a lot of training necessary, but it will not happen from today to tomorrow, it is a process."	SiPO implementation requires a lot of training and workforce change in different areas, but it is a process.	Impact on Human Roles & Employment	Human Factors and Skills
SiPO_E5	English	"In multi-crew operations, pilots rely on each other to manage emergencies, share tasks, and cross-check actions. A single pilot must handle these situations alone if systems fail."	Single-pilot operations reduce redundancy and task-sharing, increasing risk in high-stress or emergency situations.	Regulatory Framework & Safety	Human Factors and Skills

Reduction: The introduction of SiPO brings significant changes to the role of the pilot and requires adjustments to the qualifications, training and operational procedures of personnel. A single pilot must have different characteristics than in multi-crew operations, including greater independence, decision-making ability and responsibility. This shift means that pilots will require specialized training to ensure that they are able to handle advanced automation while also maintaining critical manual flying skills despite reduced practical flight time.
Another unresolved challenge is the psychological readiness of the human being, especially in long-haul flights where isolation and decision pressure can lead to mental and behavioral risks. While pilots are generally able to adapt to new technology, the effective integration of human-machine interfaces remains a key obstacle to avoid excessive reliance on automation, which has been shown to reduce human performance at critical moments.

Reducing the cockpit crew also eliminates the dynamics of collaborative problem solving, which is critical in emergency situations, and increases the pressure on individual-pilots to manage unusual situations without the safety net of a co-pilot. In addition, automation introduces a new level of complexity for air traffic controllers, requiring updated training to manage communication with the individual pilots actively controlling the aircraft.

Despite these challenges, SiPO could redistribute crew roles rather than eliminating jobs, and create new positions for system monitoring and operational safety assurance. It is important to consider that an implementation of SiPO would not only affect the situation in the cockpit but the entire aviation landscape. The high cost of the personnel shift might proof as a significant barrier.

SiPO_E1	German	"It becomes exciting when these issues are brought to the attention of the press. Opinions are formed via the press."	The public is easily influenced by the press when it comes to forming opinions.	Public Perception & Trust in Automation	Public Education & Communication
SiPO_E2	English	"To date, the only conversations on SiPO / eMCO in the public is from labor saying that it's a bad idea."	Current public discussions on SiPO/eMCO are dominated by labor unions opposing the concept.	Public Perception & Trust in Automation	Public Education & Communication
SiPO_E5	English	"If you were to ask a random person if they would now fly on a plane with only one pilot instead of two, they probably say no."	Initial public reaction to SiPO is likely negative without further information.	Public Perception & Trust in Automation	Public Education & Communication
SiPO_E5	English	"I would say currently, barely anyone knows about SiPO."	Awareness and information about SiPO	Public Perception &	Public Education & Communication

			is low among the general public.	Trust in Automation	
SiPO_E5	English	"At least if it is communicated correctly. But again, I believe that the track record is needed for certification anyway, so it is interconnected. The public trusts regulators."	Effective communication and regulatory certification are crucial for building public trust in SiPO.	Public Perception & Trust in Automation	Public Education & Communication

Reduction: Public awareness of SiPO is currently limited, and the concept is largely unknown to the general public. Where discussion does take place, it is largely shaped by trade unions, which have strongly opposed SiPO. This one-sided presentation highlights the major influence of public discourse on opinion-forming, with the media playing a crucial role in perception.

Public trust in regulators can be a critical lever for acceptance. A proven track record of safety, verified and endorsed by regulators, is essential to counter skepticism. However, the effectiveness of these efforts depends on clear and concise communication about safety and the benefits of the concept. Misconceptions or inadequate information can delay public acceptance or intensify existing concerns.

SiPO_E1	German	"I don't think trust is a big problem, because we already sit in airplanes today without knowing what's going on in the cockpit […]"	The trust of the public is not a major challenge for the implementation of the concept.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E1	German	"In the end, it's a question of price. If you want to fly to Mallorca for €15, you probably don't care."	Passengers who want to fly cheap prioritize price over other factors such as safety concerns.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E1	German	"Confidence will increase with every new generation […] confidence in technology will be higher than in my generation."	Younger generations have greater confidence in technology, potentially increasing acceptance of automation over time.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E1	German	"If these flights have been operated for 5 years and nothing has ever happened..."	Long-term operational safety records will be crucial for building public trust. Possibly in trial phases.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E1	German	"There will be an extreme rupture in the short term if one of these airplanes crashes […]"	Public trust in automation is highly fragile and susceptible to catastrophic incidents.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E1	German	"If I as an airline decide to fly with only one person... I have to think about how I can ensure that my customers continue to fly."	The airlines are responsible to maintain/ gain public trust when introducing SiPO	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E1	German	"The customer decides what to buy... then the customer has simply decided that, so the market decides that."	Market demand will ultimately determine the success of single-pilot operations.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E2	English	"From a passenger's perspective, what are the advantages to changing from the status quo?"	Passengers may question the benefits of shifting away from the current, highly reliable aviation system.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E2	English	"Public perception is linked to the technical/regulatory elements... perception that two pilots are safer than one."	Public perception is shaped by regulators as the public trust in them, currently favoring two pilots over one in aviation operations.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E2	English	"The public perception will be difficult to change considering the current environment is so very safe with very low accident rates."	Changing public perception will be challenging due to the current high safety standards in aviation.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E2	English	"The argument will have to convince the traveling public that SiPO / eMCO is the equivalent or better in terms of safety with a direct benefit to them (i.e. lower ticket prices)."	Public acceptance depends on proving that SiPO/eMCO is as safe or safer than current operations and offers clear benefits.	Public Perception & Trust in Automation	Public Perception & Trust

SiPO_E3	English	"Public perception is probably the least problematic."	The trust of the public is not a major challenge for the implementation of the concept.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E3	English	"If the SiPO system has a good track record […], they will accept it."	Long-term operational safety records will be crucial for building public trust. Possibly in trial phases.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E3	English	"If the SiPO system […] can let them fly with cheaper tickets, they will accept it."	Passengers who want to fly cheap prioritize price over other factors such as safety concerns.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E3	English	"A single crash, however, may destroy public acceptance."	Public trust in automation is highly fragile and susceptible to catastrophic incidents.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E3	English	"Most passengers have no idea how little actual flying the pilots do and how much is flown by automation on their flights. They don't know that their life is essentially in the hands of automation and the people that programmed it. They are trusting automation; they just don't know it."	The trust of the public is not a major challenge for the implementation of the concept.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E3	English	"If you build it, and it's safe, reliable, and affordable, the public will accept it. That's my belief."	Public acceptance hinges on the demonstrated safety, reliability, and affordability of the technology.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E4	English	"Public trust in SiPO is low, primarily due to fear of the unknown and high-stakes nature of air travel."	Public trust in SiPO is low.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E4	English	"Passengers feel safer knowing there are multiple pilots onboard to handle emergencies."	Passengers prefer dual-pilot operations as they are used to it and feel safer.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E4	English	"Safety assurance is paramount. Transparent testing, flawless operational records, and addressing the psychological comfort of passengers are critical for gaining acceptance."	To gain public trust, safety of SiPO has to be assured.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E5	English	"If you were to ask a random person if they would now fly on a plane with only one pilot instead of two, they probably say no."	Initial public reaction to SiPO is likely negative without further information.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E5	English	"If they understand how safe it is (which it will be if it is certified by regulators), there will be no issue with public perception."	Public trust in SiPO can improve through education on its safety and regulatory approval processes.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E5	English	"Especially if there are clear benefits for passengers, like cheaper ticket prices, it would not take long to convince most passengers."	Clear benefits like cost savings can significantly influence public acceptance of SiPO.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E5	English	"People will get used to it; it is a process."	Public acceptance of SiPO will be gradual and require time.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E5	English	"Currently, I think especially younger generations would fly on a plane with one pilot if they are cleared up about the concept beforehand."	Younger generations may be more receptive to SiPO if they are well-informed about its safety and benefits.	Public Perception & Trust in Automation	Public Perception & Trust
SiPO_E5	English	"A track record. If cargo flights are operated by one pilot over a significant period of time without any major	A proven safety track record through successful cargo operations will facilitate	Public Perception & Trust in Automation	Public Perception & Trust

		incidents, the public will accept this concept quickly."	public acceptance of SiPO.		
SiPO_E2	English	"Ticket prices will be a driver... subset of passengers that would happily grab a ride with a reduced crew."	Passengers who want to fly cheap prioritize price over other factors such as safety concerns.	Public Perception & Trust in Automation	Public Perception & Trust

Reduction: Public perception and trust play a crucial role in the implementation of SiPO. However, experts are disagreeing on whether it will be a major obstacle. Passengers already rely heavily on automation in aviation, often without realizing it. Some experts believe that public trust in SiPO must be gained over time, particularly through an impeccable operational track record. Others believe that public perception will not be a problem at all.

Proving safety is critical. Initial tests, such as cargo flights, are seen as critical to building trust. Operating accident-free for several years would help build trust, as safety remains the top priority in aviation. However, trust in automation is fragile – a single catastrophic incident could significantly erode public trust.

Airlines have a key role to play in promoting acceptance. Transparent communication, educating passengers and emphasizing benefits such as reduced ticket prices might be crucial in order to demonstrate benefits of SiPO for the passenger. Cost benefits, coupled with regulatory approval, can change public opinion over time.

Generation differences also affect acceptance. Experts believe that younger generations, who tend to be more tech-savvy, may be more open to SiPO. However, initial skepticism, particularly among older passengers, underscores the importance of effective communication and phased implementation.

Overall, public acceptance of SiPO will be a process. It depends on proven safety, clear communication and visible benefits. When these elements are in place, it is expected that public resistance will decrease over time, allowing for the gradual integration of SiPO into aviation standards.

SiPO_E1	German	"From a regulatory point of view, the regulatory authorities do not yet know how to allow it."	Regulatory authorities currently lack the framework to approve single-pilot operations.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E1	German	"Experience has shown that this takes an incredibly long time, so we're talking about 5 to 10 years."	The duration of regulatory approval processes can delay the implementation of the concept.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E1	German	"The very latest models from the major manufacturers can do an amazing amount. But none of it has yet been approved."	The major obstacle of implementation is regulation rather than technological feasibility	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E1	German	"The biggest obstacles to the concept are currently […] regulations […]."	The biggest obstacles to the concept are currently regulations.	Industry Readiness & Technology Advances	Regulatory & Certification Challenges
SiPO_E1	German	"The concepts, how it should be implemented and also the safety assessment need to be looked at again or further."	Safety assessments and implementation concepts require further development.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E1	German	"EASA is also adjusting its own roadmap further and further back in time."	Regulatory delays indicate uncertainties and challenges in achieving agreement on SiPO implementation.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E2	English	"In the post-Boeing 737-Max era... regulators will be reluctant to sign-off on newer technologies."	Regulatory adaptions will be harder to assert due to recent incidents	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E2	English	"SiPO/eMCO will require a large risk assessment by each regulatory body."	Significant risk assessments are a required condition by regulatory bodies for SiPO/eMCO implementation.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E2	English	"In the U.S., the FAA often convenes a SMS Safety Risk Management Panel (SRMP) on safety critical issues. SRMPs typically are composed of SMEs from industry, government, academia, and includes input from the end user."	In the US, industry, government, academia and end user have a certain impact on regulatory changes.	Regulatory Framework & Safety	Regulatory & Certification Challenges

SiPO_E3	English	"Certification will be extremely difficult in the USA because of the hurdles in proving equivalent safety."	A safety record of SiPO flights is needed to make certification realistic.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E3	English	"Another certification hurdle is proving equivalence in general. [...] So, the FAA will have to manufacture some requirements that allow for less than two pilots. The FAA can also be a very risk-averse agency."	Regulatory authorities currently lack the framework to approve single-pilot operations.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E3	English	"They will have to create a scientific basis for the two-crew requirement. This will be difficult because many of the important properties [...] are nebulous and difficult to quantify."	Establishing a scientific basis for two-crew operations is challenging.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E3	English	"With the only motive being lowering ticket costs and increasing profits for corporations, I do not see the political will to invest public time and resources."	Political support for regulatory adaptations is unlikely without significant public or corporate incentives.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E4	English	"Developing comprehensive frameworks to address accountability and liability in a SiPO environment."	Regulatory frameworks must address accountability and liability specific to SiPO.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E4	English	"The regulatory framework must ensure robust standards for automation testing, emergency protocols, and a clear chain of accountability."	Regulations must establish stringent standards for testing, emergency protocols, and accountability.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E4	English	"Regulatory relaxation should not occur until systems are proven unequivocally safe over an extended operational period."	Regulations should only be relaxed after extended periods of flawless safety records.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E5	English	"Regulatory challenges are the more exhausting ones. […] Regulators will be extra careful to adapt regulations for a wholly new technological concept, that has no track record yet."	Regulatory approval will be a major challenge for the implementation of SiPO.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E5	English	"The process is going to take very long, it involves not only the technological approval but also, we have to find ways to integrate the entire concept into current air traffic control systems and operational procedures."	Regulatory approval will take a long time.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E5	English	"Completely new frameworks are needed to make that work."	The current regulatory frameworks are unable to cover certifications for SiPO.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E5	English	"And of course, international consensus is needed. I do not believe that EASA would certify anything if the FAA has major concerns."	Approval from one regulatory authority is likely not enough for implementation.	Regulatory Framework & Safety	Regulatory & Certification Challenges
SiPO_E5	English	"The FAA and EASA will need to define new standards for automation systems. Current regulations are designed around multi-crew operations, where human redundancy is a key factor in managing risk."	Regulators need to create new frameworks to encompass regulations for SiPO and multi-crew flights.	Regulatory Framework & Safety	Regulatory & Certification Challenges

Reduction: Regulatory certification is one major hurdle for the implementation of SiPO.The current regulatory frameworks are closely tied to multi-crew operations, where human redundancy is key to risk management. Agencies such as FAA and EASA do not have the framework to authorize SiPO and require new standards for automation testing, contingency protocols, and responsibilities.

A major challenge is demonstrating safety equivalence to two-crew operations. In the absence of a track record, regulators are demanding comprehensive safety assessments. Recent aviation incidents, such as the Boeing 737 MAX crisis, have increased the caution of regulators and further complicated certification. Longer periods of flawless safety records will likely be required before standards can be adapted.

Creating a scientific basis to replace the two-man model is difficult. This complexity further delays progress. International harmonization presents an additional challenge, as EASA and FAA approvals are interdependent and likely have a different view on the safe feasibility of SiPO. International consensus is needed.

The regulations must also address liability and accountability while integrating SiPO into existing air traffic control and operational systems. Without a strong framework, certification is not possible. Without certification, commercial SiPO will remain a concept.
In summary, the regulatory challenges for SiPO require a new framework, rigorous safety validation e.g. in form of a track record, and international cooperation. These obstacles are likely to delay implementation by years, as certification is a lengthy process.

SiPO_E1	German	"The biggest obstacles to the concept are currently safety, […]."	Safety, regulatory challenges, and costs are the main barriers to implementing the concept.	Industry Readiness & Technology Advances	Safety & Risk Management
SiPO_E1	German	"The question you have to ask yourself is 'do we want to keep this extremely high safety standard?' or do we say, 'we accept a lower safety standard?'"	A key consideration is whether to maintain the current high safety standard or accept a reduced one.	Regulatory Framework & Safety	Safety & Risk Management
SiPO_E2	English	"Increased automation may not create a safer environment than what we have today with two highly trained pilots."	Current safety levels with two pilots may not be surpassed by automation, raising doubts about its benefits.	Regulatory Framework & Safety	Safety & Risk Management
SiPO_E3	English	"It is critical to state that there is NO safety case for SiPO/eMCO[…] And since the current system has a near-perfect safety record, you can't improve it, and the only direction you can go is the same or more accidents."	The lack of a safety case for SiPO/eMCO challenges its feasibility, as it risks degrading the aviation industry's near-perfect safety record.	Regulatory Framework & Safety	Safety & Risk Management
SiPO_E3	English	"For commercial aviation, we are pretty well maxed out for safety. […] And, there is a school of thought that says that two of the major accidents that have occurred (737MAX) have been due to more automation."	Increased automation has been linked to major accidents, raising questions about its role in enhancing safety.	Regulatory Framework & Safety	Safety & Risk Management
SiPO_E3	English	"The major milestone will be when SiPO/eMCO can be proven to provide equivalent safety."	Proving equivalent safety is the critical milestone for SiPO/eMCO implementation.	Future Outlook & Strategic Vision	Safety & Risk Management
SiPO_E4	English	"Cybersecurity vulnerabilities."	Cybersecurity risks pose challenges to SiPO implementation.	Industry Readiness & Technology Advances	Safety & Risk Management
SiPO_E4	English	"Safety assurance is paramount. Transparent testing, flawless operational records, and addressing the psychological comfort of passengers are critical for gaining acceptance."	Transparent testing and perfect safety records are essential for public acceptance of SiPO.	Public Perception & Trust in Automation	Safety & Risk Management
SiPO_E4	English	"While innovation is essential, safety must remain the aviation industry's top priority."	Safety should always take precedence over rapid technological innovation in aviation.	Regulatory Framework & Safety	Safety & Risk Management
SiPO_E5	English	"We simply cannot rely on it yet."	There are still safety concerns.	Regulatory Framework & Safety	Safety & Risk Management
SiPO_E5	English	"There are solutions through remote support from the ground, where the plane can remotely be landed."	Remote support systems offer potential solutions for pilot incapacitation.	Industry Readiness & Technology Advances	Safety & Risk Management

Reduction: Safety remains a major challenge in the introduction of SiPO. Current safety standards in aviation are exceptionally high, and any deviation from these standards could undermine public confidence and the industry's close to flawless safety record. While advances in automation hold potential, they have also been associated with critical failures, such as the 737 MAX incidents, which shows the dangers of over-reliance on technology without robust safeguards. Demonstrating that SiPO can provide the same level of safety as two pilots is a critical milestone that must be met before implementation can proceed.

The viability of SiPO firstly depends on solving several safety issues. Transparent testing, error-free operational records and solutions for when a pilot incapacitates, such as ground-based remote assistance systems, are essential to ensure safety.

Ultimately, experts agree that safety in aviation must be the top priority. All steps of innovation must be accompanied by rigorous testing and comprehensive risk mitigation strategies to ensure that technological advances do not jeopardize the industry's long-standing safety record.					
SiPO_E1	German	"If you look at the technology, it's all solvable. So, all the problems that we have identified on the technical side are solvable or have already been partially solved."	Technologically, the concept is feasible. The major implementation challenges lie elsewhere.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E1	German	"It starts with such trivial things as when the single pilot has to go to the toilet. […] What happens if this person has a heart attack? What does the airplane do then?"	Very particular and practical issues like single-pilot physical conditions require regulatory (or technical) solutions.	Regulatory Framework & Safety	Technological Readiness
SiPO_E1	German	"We need to take another look at the whole area of data link technology... Global data link is exciting. […] The whole area of system jamming, especially with the conflicts we have in the world right now..."	Advancements in cyber security are crucial for the feasibility of single-pilot operations.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E1	German	That's a bit of the reason why we don't yet have self-driving trains, for example.	The absence of autonomous trains casts doubts on feasibility.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E2	English	"As a line pilot... I am skeptical about reduced pilot operations in current generation aircraft operating in the national airspace."	Current generation aircraft pose challenges for SiPO/eMCO.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E2	English	"The technology is feasible in a sterile environment, but... becomes much more difficult to accomplish safely in complex scenarios. […] SiPO/eMCO material does not provide safe solutions for pilot incapacitation events... other debilitating conditions."	Existing SiPO/eMCO frameworks lack adequate solutions for various pilot incapacitation scenarios, posing significant risks.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E3	English	"For completely normal operations, from a technical perspective, I feel that we have all the technology needed."	Technology does not pose a challenge for SiPO in normal flight conditions.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E3	English	"Why aren't there any autonomous freight trains, and why do we think that we can have autonomous aircraft in a 6-degree-of-freedom environment when we don't have autonomous freight trains in a 2-dof environment?"	The absence of autonomous freight trains raises doubts about the feasibility of fully autonomous aircraft.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E4	English	"While advancements in automation technology are impressive, I believe SiPO is not yet operationally or commercially ready. The technology faces significant challenges in ensuring redundancy, reliability, and decision-making capabilities that match human judgment in complex scenarios."	SiPO technology is not yet sufficiently advanced for safe operational or commercial use.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"The technology is coming along quickly, but we're not quite ready to roll it out for everyday commercial flights yet."	SiPO technology is progressing rapidly but is not yet ready for widespread commercial use.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"Autopilot systems today can handle a lot more than just keeping the plane on course."	Current technology is already underestimated in terms of functionality.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"Modern planes have backups for just about everything—power, navigation, and even the controls."	Modern planes already have redundancy that is necessary for SiPO.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"There are parties from industry and research who are testing systems where ground-based teams can step in	Research in this field is advanced, successful test	Industry Readiness &	Technological Readiness

		to support pilots in real-time. Airbus has already conducted even fully autonomous test flights with large commercial aircraft."	flights show the feasibility of the concept.	Technology Advances	
SiPO_E5	English	"The remaining 30% involves refining these systems to meet stringent safety and operational standards."	Safety and operational standards are not met yet.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"The primary challenge is ensuring that automation systems are reliable and capable of handling complex, unpredictable scenarios. [...] These systems need to demonstrate flawless performance under extreme conditions."	A key challenge is the reliability of the technology in complex situations.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"The unpredictability is the problem. [...] I believe that for most flights the technology is advanced enough to operate a single pilot flight without any problems. [...] what happens in the case of pilot incapacitation or other extreme scenarios? It is rare but there is no reliable solution... yet."	The technology already advanced enough to handle most scenarios, however, is not reliable enough to reliably handle rare extreme situations.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"I am convinced that it is all solvable."	The technological realization is not a major challenge.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"Humans can adapt to different situations, there are some bizarre situations that we probably have never seen before. A human can adapt, a machine not yet."	Human adaptability remains critical in unpredictable and novel flight scenarios where machines may fail to respond effectively.	Regulatory Framework & Safety	Technological Readiness
SiPO_E5	English	"If the pilot is incapacitated, the machine has to do it alone. We simply cannot rely on it yet."	Pilot incapacitation presents a significant challenge for safety, as current technology lacks reliability in such scenarios.	Industry Readiness & Technology Advances	Technological Readiness
SiPO_E5	English	"At some point, the technology will be advanced enough to be very reliable even in these situations, but that is really far in the future."	Reliable automation to handle pilot incapacitation is a long-term goal requiring significant advancements.	Regulatory Framework & Safety	Technological Readiness

Reduction: The technological basis for SiPO is advancing quickly, and most technical challenges are considered solvable by experts. Today's systems already have advanced capabilities like autopilot functions and high redundancy for power supply, navigation and control. Successful autonomous test flights by Airbus underscore the feasibility of the concept under controlled conditions. However, critical gaps remain. Existing systems struggle to cope with complex, unpredictable scenarios, and robust solutions for pilot incapacitation are lacking, which is a critical safety issue.

While current technology is adequate for routine flight operations, its reliability decreases in extreme or rare situations where human adaptability cannot be replaced by technology yet. Problems such as the pilot's physical condition, cyber security risks and operational challenges with aircraft in the current generation would further complicate implementation. Although the concept is technically feasible, it will take a lot of time and further development to achieve the necessary safety and operational standards for widespread commercial use.

The lack of fully autonomous systems in simpler modes of transportation, such as freight trains, also raises questions about the practicality of such systems in the more complex environment of aviation.

A.3.1.3 Autonomous UAM Experts

Expert Number	Interview Language	Paraphrase	Generalization	Category	Code
UAM_E3	German	"Typical technology lifecycle: early adopters, adventurous people, or	Early adopters will lead initial use.	Public Perception &	Adoption Lifecycle

		those with trust in the system will use it initially."		Trust in Automation	
UAM_E3	German	"It's like the Technology Adoption Lifecycle: you start with tech enthusiasts, then visionaries, pragmatists, conservatives, and skeptics."	Adoption follows the tech lifecycle.	Public Perception & Trust in Automation	Adoption Lifecycle
UAM_E3	German	"It's a mindset thing and about convincing the masses by the early adopters creating a domino effect."	Early adopters spark mass acceptance.	Public Perception & Trust in Automation	Adoption Lifecycle
UAM_E4	English	"People's opinions are often shaped by their exposure to the technology."	Exposure shapes the public opinion.	Public Perception & Trust in Automation	Adoption Lifecycle
UAM_E5	German	"For early adopters, flying in one might be exciting, but for others, having these vehicles above their homes can feel intrusive."	Enthusiasts are excited; others feel intrusion.	Public Perception & Trust in Automation	Adoption Lifecycle
UAM_E7	English	"The adoption curve will follow the standard life cycle, starting with early adopters and gradually expanding as trust builds."	Adoption will grow as trust builds.	Public Perception & Trust in Automation	Adoption Lifecycle
UAM_E9	German	"The transition won't happen overnight, with thousands of vehicles suddenly appearing in the sky. Initially, there will be enough enthusiasts eager to try it out."	Growth will start rather slow with enthusiasts.	Public Perception & Trust in Automation	Adoption Lifecycle
UAM_E9	German	"Convincing the broader public will require demonstrating that these technologies can integrate seamlessly into daily life without causing negative disruptions."	Integration without disruption is key.	Public Perception & Trust in Automation	Adoption Lifecycle

Reduction: The adoption of autonomous UAM is expected to follow a classic technology lifecycle, beginning with early adopters. These individuals—typically adventurous people or tech enthusiasts with inherent trust in new systems—are likely to lead the initial use phase. Early adopters play a crucial role in shaping public perception by creating a domino effect that gradually convinces the broader public of the technology's viability. Exposure to the technology is a key factor in this process, as it helps shape opinions, whether positively or negatively. While early adopters might find the experience exciting, others may initially view the presence of such vehicles as intrusive or disruptive.

This transition will be gradual rather than immediate, with adoption expanding incrementally as trust in the system builds. The broader public will need to be convinced that autonomous UAM can integrate seamlessly into daily life without causing significant disruptions or negative effects. Demonstrating this level of reliability and harmony with existing systems will be essential for widespread acceptance. Over time, the lifecycle will progress as trust grows, leading to broader adoption and eventual normalization of autonomous UAM as a practical transportation option.

UAM_E1	English	"Airspace management poses questions about collision risks and responsibilities."	Collision risks and responsibilities need solutions.	Regulatory Framework & Safety	Airspace Management
UAM_E1	English	"How do you handle multiple bird strikes or determine liability in such events? These are issues we don't yet have clear answers to."	Liability for bird strikes remains unclear.	Regulatory Framework & Safety	Airspace Management
UAM_E1	English	"Drones […] are less predictable than traditional aircraft, requiring larger airspace volumes per drone, which reduces capacity."	Drones need more airspace, reducing capacity.	Industry Readiness & Technology Advances	Airspace Management
UAM_E1	English	"The biggest challenge lies in the interaction between all the different airspace users."	Managing diverse airspace users is challenging.	Industry Readiness & Technology Advances	Airspace Management
UAM_E1	English	"Flight corridors might be an option, but they introduce trade-offs […] they create congestion in designated zones."	Flight corridors create congestion trade-offs.	Industry Readiness & Technology Advances	Airspace Management
UAM_E1	English	"There's also the question of what happens if something unexpected occurs, like a flock of birds."	Handling unexpected events like bird flocks is unresolved.	Regulatory Framework & Safety	Airspace Management

UAM_E1	English	"Should the drone deviate from its path? If so, by how much? How does that affect other drones or aircraft? None of these rules are standardized yet. There are competing philosophies about how to handle such scenarios, but no consensus exists. This lack of agreement creates delays in establishing safe and efficient systems."	Path deviation rules are not standardized.	Regulatory Framework & Safety	Airspace Management
UAM_E1	English	"User perception is a critical aspect, but another major challenge lies in airspace management."	Perception and airspace management are key issues.	Public Perception & Trust in Automation	Airspace Management
UAM_E1	English	"If an aircraft needs to change direction mid-flight due to a bird strike […]. How much freedom should it have to make decisions? How would these deviations impact other aircraft? None of these questions have standardized answers."	Rules for mid-flight course changes remain undefined.	Regulatory Framework & Safety	Airspace Management
UAM_E2	English	"Collision avoidance calls for ensuring that autonomous drones can detect and avoid obstacles, including other aircraft, people, and infrastructure."	Collision avoidance requires reliable obstacle detection.	Regulatory Framework & Safety	Airspace Management
UAM_E3	German	"This is largely due to airspace integration issues. […] As more vehicles enter the airspace, it becomes increasingly complex."	Airspace integration becomes harder with more eVTOLs.	Industry Readiness & Technology Advances	Airspace Management
UAM_E3	German	"First, you have Air Operations Rules, which define things like flight altitude and operational procedures. Then there's Airspace Integration, which deals with how different types of aircraft coexist in the same airspace, like drones and commercial planes. Finally, there are infrastructure rules, which specify the infrastructure needed to ensure safety."	Rules for operations and airspace integration are critical.	Regulatory Framework & Safety	Airspace Management
UAM_E3	German	"Communication and especially integrating with airspace is a primary concern. […] Integrating into the airspace system is the biggest challenge – making sure everything works together seamlessly."	Effective communication and seamless integration with existing airspace systems are critical safety priorities.	Regulatory Framework & Safety	Airspace Management
UAM_E3	German	"Managing unexpected elements, like birds or other airborne objects, is another concern."	Handling airborne hazards like birds is a concern.	Regulatory Framework & Safety	Airspace Management
UAM_E4	English	"The current systems aren't ready to handle local issues or manage collision avoidance effectively."	Existing systems lack the capability to address operational challenges and effective collision avoidance.	Industry Readiness & Technology Advances	Airspace Management
UAM_E5	German	"Integration into airspace is critical. What happens in unforeseen situations? How do we handle emergencies?"	Handling unforeseen situation remains unclear.	Industry Readiness & Technology Advances	Airspace Management
UAM_E5	German	"Most of the required technologies already exist. It's more about integration than purely technological innovation."	Existing tech needs better integration, not reinvention.	Industry Readiness & Technology Advances	Airspace Management
UAM_E6	German	"In lower airspace, where conditions can change rapidly, automated systems are far better equipped to handle challenges like sudden obstacles or adverse weather."	Automated systems excel in dynamic low airspace conditions.	Industry Readiness & Technology Advances	Airspace Management
UAM_E6	German	"Developing robust flight management systems and autonomous airspace management will be critical."	Robust flight and airspace management systems are essential.	Future Outlook & Strategic Vision	Airspace Management

UAM_E7	English	"Managing hundreds or thousands of eVTOLs will likely be a bigger challenge than noise."	Managing large eVTOL fleets is a bigger challenge than noise.	Industry Readiness & Technology Advances	Airspace Management
UAM_E8	German	"Navigation accuracy, real-time coordination, and bad-weather performance are critical areas. The technology is advanced enough to address these, but the transition from current systems to new ones must be carefully managed."	Accurate navigation and weather handling are key.	Regulatory Framework & Safety	Airspace Management
UAM_E9	German	"New flying objects must interact with existing ones. There are corridors where they are prohibited and others where they are permitted. […] Managing interference with existing flying objects like helicopters, police, ambulances, and commercial air traffic is crucial, especially near airports."	New aircraft must integrate with existing air traffic.	Regulatory Framework & Safety	Airspace Management
UAM_E10	English	"Developing automated systems for real-time demand analysis and airspace management will also be crucial to ensure efficient operations in urban settings."	Real-time demand and airspace management are crucial for urban operations.	Industry Readiness & Technology Advances	Airspace Management

Reduction: Airspace integration and management present significant challenges for the successful deployment of autonomous UAM systems. Key issues include collision risks, liability for events such as bird strikes, and the absence of standardized rules for path deviations or mid-flight course changes. The unpredictability of drones compared to traditional aircraft necessitates larger airspace volumes per vehicle, reducing overall capacity and complicating integration with other airspace users. Effective communication and seamless interaction between diverse aircraft types—such as drones, eVTOLs, helicopters, and commercial planes—are critical to ensure safety and efficiency.

Managing unexpected elements, such as flocks of birds or sudden obstacles, is another unresolved concern. Automated systems are well-suited for rapidly changing conditions in low-altitude airspace but require robust flight management and collision avoidance technologies. While much of the necessary technology exists, the challenge lies in integrating these systems into current airspace operations. Real-time demand analysis, accurate navigation, and reliable performance in adverse weather conditions are essential for maintaining efficiency in increasingly crowded skies.

Additionally, proposed solutions like flight corridors bring trade-offs, such as congestion in designated zones. Ensuring that new flying vehicles coexist with existing air traffic, particularly near sensitive areas like airports, requires carefully coordinated infrastructure and operational rules. Developing autonomous airspace management systems that handle these complexities will be essential for scaling operations, as managing large fleets of eVTOLs is expected to be more challenging than issues like noise. Achieving seamless airspace integration remains one of the primary hurdles to widespread adoption of autonomous UAM technologies.

UAM_E2	English	"Cybersecurity is an important aspect […] ensure protection against cyber threats and ensuring system integrity."	Cybersecurity is essential for system protection and integrity.	Regulatory Framework & Safety	Cybersecurity & Data Privacy
UAM_E4	English	"Protecting systems from unauthorized access and ensuring data privacy are major challenges. […] Cybersecurity risks include potential attacks that could disrupt operations, compromise safety, or spread viruses across the entire system."	Cybersecurity challenges include unauthorized access, disruptions, and safety risks.	Regulatory Framework & Safety	Cybersecurity & Data Privacy
UAM_E4	English	"Data privacy is also critical – people need assurance that their information is secure and won't be exploited."	Data privacy is key to building user trust in autonomous systems.	Regulatory Framework & Safety	Cybersecurity & Data Privacy
UAM_E6	German	"Cybersecurity will also be a critical area – ensuring that these systems aren't vulnerable to attacks will require building new competencies. As automation increases, cybersecurity will become even more critical."	Increasing automation heightens the need for robust cybersecurity measures.	Regulatory Framework & Safety	Cybersecurity & Data Privacy
UAM_E7	English	"Cybersecurity is another major concern. Currently, pilots act as a safeguard against hacking or unauthorized control. Autonomous systems will need to be robust	Autonomous systems must address cybersecurity risks without human fallback.	Regulatory Framework & Safety	Cybersecurity & Data Privacy

		enough to prevent unauthorized access."			
UAM_E9	German	"Cybersecurity might still be a potential issue"	Cybersecurity remains a potential concern for autonomous systems.	Regulatory Framework & Safety	Cybersecurity & Data Privacy

Reduction: Cybersecurity is a critical challenge for autonomous UAM, requiring robust measures to ensure system integrity, protect against unauthorized access, and safeguard data privacy. As automation increases, the risk of cyber threats—such as disruptions, safety compromises, or the spread of malware across interconnected systems—becomes more significant. Users must be assured that their personal information is secure and protected from exploitation, as trust in system security is essential for widespread adoption.

Unlike traditional aviation, where pilots provide a safeguard against unauthorized control, autonomous systems lack such human oversight, heightening the need for advanced cybersecurity solutions. Developing these systems will demand new competencies and innovative strategies to prevent vulnerabilities. Addressing cybersecurity effectively is crucial to maintaining operational safety, user trust, and the overall resilience of autonomous UAM networks, making it a top priority for industry stakeholders.

UAM_E1	English	"Whether you want it or not, it becomes a question of resources. It's no longer about how many aircraft you need, but rather about […] the economic capacity to support operations."	Resource availability and economic capacity determine scalability.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E1	English	"In a European capital city, we analyzed use cases...None of these use cases were economically viable. […] Our study concluded there wasn't a single viable use case for UAM within traditional financial metrics."	UAM use cases often fail to meet traditional financial viability metrics.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E1	English	"I'm honestly not particularly optimistic about the timeline for this technology becoming commercially viable."	The commercial viability timeline for UAM technology is uncertain.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E2	English	"Reducing production costs and making these solutions affordable on a large scale remains a challenge."	Affordability and cost reduction are key challenges for scaling UAM solutions.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E3	German	"It hasn't been pushed that far yet for commercial reasons"	Limited commercial testing hinders technological readiness.	Industry Readiness & Technology Advances	Economic & Financial Viability
UAM_E3	German	"Eliminating pilots reduces complexity and costs, enabling more accessible pricing for short-haul flights."	Removing pilots reduces costs and improves accessibility.	Industry Readiness & Technology Advances	Economic & Financial Viability
UAM_E3	German	"It ultimately depends on funding and commercialization to determine when it will truly take off."	Funding and commercialization are critical for UAM's progress.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E4	English	"Cost is definitely a factor. We don't yet have comprehensive data on life cycle costs, particularly given the use of electric power and batteries."	Lack of data on life cycle costs complicates financial planning	Industry Readiness & Technology Advances	Economic & Financial Viability
UAM_E5	German	"Cost savings also play a role, but safety remains the most critical aspect."	Safety is the priority despite potential cost savings.	Regulatory Framework & Safety	Economic & Financial Viability
UAM_E5	German	"Aiming directly for autonomous passenger transport overpopulated areas is far more ambitious and requires significant upfront investment."	Urban autonomous transport requires high investment and ambition.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E5	German	"The leverage from removing a pilot in UAM is much greater than in commercial aviation. […] removing the pilot frees up space for one more passenger or extra payload. […] The economic incentive for autonomy is far greater in eVTOLs. "	Autonomy in UAM offers higher economic incentives than commercial aviation.	Future Outlook & Strategic Vision	Economic & Financial Viability
UAM_E6	German	"All the players are, of course, working towards autonomy eventually because, commercially, it	Autonomy is essential for the commercial viability of air taxis.	Future Outlook & Strategic Vision	Economic & Financial Viability

		doesn’t make sense to have a pilot in every air taxi."			
UAM_E6	German	"Boeing’s primary motivation behind funding Wisk seems to be less about launching air taxis and more about using those technologies in commercial aviation."	Boeing uses UAM technologies to benefit commercial aviation.	Comparative Analysis Across Industries	Economic & Financial Viability
UAM_E6	German	"The challenge of finding a viable business model – it’s still unclear what works economically for operators."	Viable business models for UAM remain uncertain.	Industry Readiness & Technology Advances	Economic & Financial Viability
UAM_E8	German	"A significant challenge is structuring and managing high investments in a way that generates viable products along the way."	Managing investments effectively is crucial for creating viable UAM products.	Industry Readiness & Technology Advances	Economic & Financial Viability
UAM_E8	German	"Costs are definitely a significant factor. Research and development expenses remain high, and there’s still a lot of need for innovation."	High R&D costs and innovation needs are significant hurdles.	Industry Readiness & Technology Advances	Economic & Financial Viability
UAM_E8	German	"Companies need to take on significant risks to operate profitably."	Profitability in UAM requires companies to take significant risks.	Regulatory Framework & Safety	Economic & Financial Viability
UAM_E8	German	"There are few players in this space, and when one fails, it hurts the entire industry. Public perception worsens, making it harder for others to secure funding."	Failures in UAM harm industry perception and funding opportunities.	Public Perception & Trust in Automation	Economic & Financial Viability
UAM_E9	German	"Most of the companies active in this area are start-ups. Airbus and Boeing are exceptions, but their work in this field is cross financed through other business units. The majority of companies involved, particularly those manufacturing flying objects, rely heavily on venture capital. The strategic direction these companies take is influenced by the level of pressure they face from investors. "	Start-ups dominate UAM, relying on venture capital and investor-driven strategies.	Future Outlook & Strategic Vision	Economic & Financial Viability

Reduction: The economic and financial viability of autonomous UAM faces significant challenges, particularly in achieving scalability and affordability. Resource availability and economic capacity are critical determinants, but traditional financial metrics often deem UAM use cases unviable, especially in densely populated urban areas. High research and development costs, combined with the need for substantial upfront investments, further complicate the commercialization timeline, leaving the path to profitability uncertain.

Removing pilots offers considerable economic incentives by reducing costs and enabling greater passenger or payload capacity, making autonomy essential for air taxi operations. However, life cycle cost data remains incomplete, particularly regarding electric power and battery usage, which complicates financial planning. The industry heavily relies on venture capital, with start-ups dominating the space, while larger players like Airbus and Boeing cross-finance their UAM initiatives through other business units.

Viable business models for UAM remain undefined, requiring companies to take significant risks amidst high investment pressures. Failures in the sector negatively impact public perception and funding opportunities, creating further obstacles for commercialization. Despite these challenges, the economic incentives of autonomy and cost reduction drive continuous innovation, making effective investment management and risk-taking pivotal for the sector's long-term viability.

UAM_E1	English	"Many companies are stuck in a ‘fake it till you make it’ loop […] burn through billions in cash while asking for more. […] This constant cycle of updates makes it nearly impossible to reach the finish line.""	UAM companies face challenges with unsustainable funding cycles.	Future Outlook & Strategic Vision	Future Outlook
UAM_E2	English	"Milestones depend on technological advancements, regulatory adaptations, and public education and acceptance."	Achieving milestones requires progress in technology, regulation, and public trust.	Future Outlook & Strategic Vision	Future Outlook
UAM_E4	English	"There are different types of milestones – technological, societal, and regulatory."	UAM milestones span technology, society, and regulation.	Future Outlook & Strategic Vision	Future Outlook
UAM_E5	German	"eVTOLs will only truly take off—both figuratively and literally—once they are autonomous."	UAM success depends on achieving full autonomy.	Future Outlook & Strategic Vision	Future Outlook

UAM_E7	English	"Remote piloting is already established. Automation for low-stakes cases, like small cargo drones, also exists. The next step is proving the technology for larger aircraft. This involves demonstrating that the hardware and software can handle failures."	Advancing automation requires proving reliability for larger aircraft.	Future Outlook & Strategic Vision	Future Outlook
UAM_E1	English	"Setting up rules for airspace usage, or 'U-Space,' will be critical, and as long as the ball keeps rolling, people will keep developing designs and waiting for certification."	Clear airspace usage rules are essential for UAM progress.	Future Outlook & Strategic Vision	Future Outlook
UAM_E7	English	"Main competitor isn't Airbus; it's Uber."	UAM focuses more on traffic management than competing with traditional aviation.	Future Outlook & Strategic Vision	Future Outlook
UAM_E8	German	"Conventional aircraft could adopt automation sooner than eVTOLs. Companies like Reliable Robotics or Xwing are building autopilots that could theoretically fit into any aircraft."	Automation in traditional aviation may progress faster than in UAM.	Future Outlook & Strategic Vision	Future Outlook
UAM_E10	English	"Key milestones include identifying optimal vertiport sites based on safety, accessibility, and integration with existing infrastructure."	Selecting vertiport locations is a key milestone for UAM development.	Future Outlook & Strategic Vision	Future Outlook

Reduction: The future of autonomous UAM hinges on achieving key milestones in technology, regulation, and societal acceptance. Companies in the sector face challenges with unsustainable funding cycles, often struggling to secure sufficient resources to reach the finish line. Full autonomy remains a critical goal for the industry's success, as remote piloting and automation for smaller cargo drones are already established. The next step involves proving the reliability of hardware and software for larger aircraft, ensuring they can handle failures effectively.

Regulatory progress, such as setting clear rules for airspace usage (U-Space), is essential to facilitate development and certification. Identifying optimal vertiport locations based on safety, accessibility, and integration with existing infrastructure is another crucial milestone. While UAM focuses on urban traffic management, its primary competition lies outside traditional aviation, with companies like Uber targeting similar markets.

Automation may advance faster in traditional aviation, where companies like Reliable Robotics and Xwing develop adaptable autopilot systems. However, UAM's success ultimately depends on continuous innovation, overcoming funding challenges, and aligning technological progress with public trust and regulatory adaptation. These factors collectively shape the path to achieving a sustainable and scalable future for UAM.

UAM_E1	English	"The skills required might not change significantly. Air traffic management already involves optimizing traffic and volumes."	Regional differences define UAM progress: China builds, the U.S. innovates, Europe regulates.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E1	English	"These aren't technical workforce skill issues – they're decisions about risk management and operational design."	Workforce challenges are more about risk management and operational design than technical skills.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E1	English	"While there may be marginal changes in workforce skills, the overall impact on capacity and workforce requirements will be limited."	Workforce impacts will be minimal, with only slight skill adjustments needed.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E2	English	"The workforce will need expertise in areas like data analysis, artificial intelligence, machine learning, cybersecurity, and systems integration."	Advanced technical skills, including AI and cybersecurity, will be critical for UAM.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E2	English	"They'll also need strong skills in user experience design and regulatory compliance."	User experience and regulatory compliance skills will play an essential role in UAM adoption.	Impact on Human Roles & Employment	Human Factors & Skills

UAM_E2	English	"These competencies will be essential as automation continues to evolve and become more integrated into operations."	Evolving UAM automation will require continuous skill development across multiple domains.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E3	German	"Before we have fully autonomous passenger drones, there will be operational control centers where trained drone pilots can intervene remotely."	Remote control centers will manage operations before full UAM autonomy is achieved.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E3	German	"It's about whether the aircraft flies completely autonomously or if there's an emergency system with human intervention."	Balancing autonomous systems with human emergency intervention is crucial for UAM safety.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E3	German	"Having a remote pilot makes things much simpler […] If you remove the human element entirely, you quickly enter ethical territory."	Remote pilots simplify operations and mitigate ethical concerns in autonomous UAM.	Regulatory Framework & Safety	Human Factors & Skills
UAM_E4	English	"The workforce would need to act fast, detect when an autonomous system hasn't made the right decision, and intervene as needed."	Future UAM workforce must swiftly detect and address autonomous system errors.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E5	German	"Roles will change. There will still be a need for human intervention in emergencies."	Human intervention will remain necessary during emergencies in UAM operations.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E5	German	"We'll need people to supervise flights remotely, not only at early stages but also later."	Long-term UAM operations will require remote flight supervision by skilled personnel.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E5	German	"Having someone available to intervene, even though statistics show most accidents are caused by human error."	Human oversight will provide psychological comfort, despite data favoring automation.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E5	German	"These roles will change significantly. Today's air traffic controllers monitor ongoing operations and communicate with pilots as needed. In the future, they might only be contacted during emergencies"	UAM automation will shift air traffic control roles toward emergency response only.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E5	German	"Supervisors will likely manage multiple flights simultaneously – far more than current air traffic controllers handle. This will require fewer people overall but with much higher qualifications."	Automation will reduce workforce demand but require more highly skilled supervisors.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E6	German	"Need for autonomous airspace management systems – systems that can manage traffic without human controllers. Traditional air traffic controllers are already stretched thin, and there's a severe talent shortage."	Autonomous airspace management systems are necessary to address controller shortages.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E6	German	"Lufthansa Aviation Training is already exploring how one pilot could manage multiple UAM vehicles remotely. […] A similar model could be applied to UAM."	Training programs are exploring models for single operators managing multiple UAM vehicles.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E6	German	"Remote piloting and the ability to manage multiple UAM vehicles simultaneously will require specialized training and new skill sets."	Specialized training is essential for managing multiple UAM vehicles remotely.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E8	German	"Traditional cockpit setups won't work when you're remote [...] The role becomes [...] a kind of traffic manager who monitors multiple drones at once to reduce costs, rather than a single pilot dedicated to one vehicle. That becomes increasingly complicated when you scale hundreds	Remote management roles in UAM require scalable systems for overseeing multiple drones efficiently.	Impact on Human Roles & Employment	Human Factors & Skills

		of drones in a city. Then you'll need a system capable of handling that kind of complexity."			
UAM_E9	German	"Autonomous technology doesn't have a big problem in principle, because the advantage of autonomous technologies in this area is supposed to be that it actually saves costs. Pilots, for instance, will sooner or later reflect cost savings in the number of missions you fly."	Autonomous UAM offers significant cost savings by reducing pilot dependency.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E9	German	"Heavily coding-based, with new types of drive systems and engineering capabilities needed for electrification."	Development of UAM demands advanced coding and engineering skills, especially for electrification.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E9	German	"The stress levels for air traffic controllers, for instance, will increase significantly."	Increased UAM operations will raise stress levels for air traffic controllers.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E9	German	"There needs to be a balance where you don't just deploy more people but instead use digital support measures to relieve this stress."	Digital tools are necessary to reduce controller workload and manage UAM operations.	Impact on Human Roles & Employment	Human Factors & Skills
UAM_E10	English	"Skills such as understanding operations, interpreting data, validating data accuracy, fostering alignment across teams, problem-solving, and the ability to collaborate effectively in interdisciplinary settings will be crucial."	Interdisciplinary collaboration and operational problem-solving will be key workforce skills.	Impact on Human Roles & Employment	Human Factors & Skills

Reduction: The rise of autonomous UAM will bring changes to workforce roles and required skills, though the overall impact on employment capacity may be limited. Technical expertise in areas such as artificial intelligence, machine learning, cybersecurity, and systems integration will be essential, alongside strong skills in user experience design and regulatory compliance. As automation evolves, the workforce must adapt, with roles shifting toward remote supervision, data analysis, and emergency intervention.

Before achieving full autonomy, operational control centers with trained drone pilots will oversee UAM operations, ensuring human intervention remains available for emergencies. Remote pilots and supervisors will manage multiple flights simultaneously, requiring advanced training and higher qualifications. This shift will reduce the overall workforce demand while emphasizing the need for highly skilled personnel capable of handling complex systems. Air traffic controllers, for example, will transition from active monitoring to emergency response roles, supported by autonomous airspace management systems to address current talent shortages and workload stress.

The integration of UAM also demands specialized training for managing scalable operations and balancing human oversight with automated systems. Interdisciplinary collaboration, problem-solving, and the ability to validate and interpret operational data will be critical workforce competencies. Digital tools will play a vital role in relieving stress and improving efficiency, as traditional cockpit and traffic management setups evolve to accommodate the complexity of autonomous UAM operations. Overall, while the dependency on human operators will decrease, the demand for advanced skills and innovative workforce roles will grow to support the safe and efficient deployment of autonomous UAM.

UAM_E1	English	"The overall system […] refers to what it takes to make everything work together. That's much trickier, and we're perhaps limited. […] There's already a shortage of battery materials globally."	Integrating UAM systems and addressing resource shortages are significant challenges.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E1	English	"You need a lot of energy. Questions arise such as what kind of energy you use, where you find the resources."	Energy sourcing and sustainability are critical issues for UAM scalability.	Future Outlook & Strategic Vision	Infrastructure Gaps
UAM_E1	English	"Infrastructure is another key issue. […] You need to clear landing paths, which might involve cutting down trees – an unpopular choice given today's focus on combating climate change."	Infrastructure development for UAM must align with environmental sustainability goals.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E1	English	"Communication networks, like 5G, are another challenge […] adapting them to aerial scenarios is difficult."	Adapting 5G networks for aerial applications	Industry Readiness &	Infrastructure Gaps

			poses significant technical challenges.	Technology Advances	
UAM_E2	English	"System failures obviously play a significant role […] including both software and hardware malfunctions."	Addressing software and hardware failures is vital for safe UAM operations.	Regulatory Framework & Safety	Infrastructure Gaps
UAM_E2	English	"Advanced sensors and perception systems are utilized to enhance situational awareness."	Advanced sensor technology is critical for situational awareness in UAM systems.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E3	German	"The aircraft must communicate with the airspace and the local aerodrome, which adds complexity."	Effective communication with airspace and aerodromes is essential but complex.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E3	German	"Communication and infrastructure – specifically ground infrastructure – play a significant role."	Shared communication and ground infrastructure are critical for UAM integration.	Comparative Analysis Across Industries	Infrastructure Gaps
UAM_E4	English	"Infrastructure costs also haven't been widely explored, such as recharging systems and their locations. While operational costs might be lower than in other transport modes, infrastructure costs are likely to be higher."	High infrastructure costs, particularly for recharging systems, remain unexplored barriers.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E4	English	"Identifying vertiport locations and defining energy requirements are also necessary steps."	Planning vertiport locations and energy requirements is critical for UAM success.	Regulatory Framework & Safety	Infrastructure Gaps
UAM_E5	German	"Most hurdles are more about diligence than innovation […] cameras and LiDAR – isn't revolutionary, but it's essential."	UAM technology requires meticulous integration rather than radical innovation.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E5	German	"There's a clear distinction between passenger drones and cargo drones. The requirements differ significantly."	Passenger and cargo drones have unique and distinct operational requirements.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E6	German	"Reliable, high-speed connectivity is essential for managing autonomous UAM fleets. Without 5G, autonomous UAM is impossible. For V2V communication in a shared airspace, you need widespread and highly advanced bandwidth communication."	High-speed connectivity, such as 5G, is essential for autonomous UAM operations.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E6	German	"Without robust infrastructure, scaling will be impossible. Addressing this will require significant investment in telecommunications infrastructure."	Scaling UAM operations depends on substantial investment in reliable telecommunications infrastructure.	Future Outlook & Strategic Vision	Infrastructure Gaps
UAM_E7	English	"Autonomous aircraft need to communicate with the network and other aircraft seamlessly. New systems will need to be developed."	Seamless communication systems between aircraft and networks are critical for UAM.	Industry Readiness & Technology Advances	Infrastructure Gaps
UAM_E9	German	"Infrastructure has two components: airspace integration and digital infrastructure for communication between vehicles."	UAM infrastructure combines airspace integration with vehicle communication systems.	Industry Readiness & Technology Advances	Infrastructure Gaps

Reduction: The successful deployment of autonomous UAM hinges on developing robust infrastructure and integrated systems capable of addressing significant technical and resource challenges. Key requirements include seamless communication networks, such as high-speed 5G connectivity, to enable reliable vehicle-to-vehicle (V2V) and network communication. Adapting these systems for aerial scenarios is a complex technical hurdle, yet essential for managing autonomous fleets and ensuring safe operations.

Energy sourcing and sustainability are critical issues, as UAM systems demand substantial resources, including battery materials, which are already in global shortage. Infrastructure development, such as vertiport locations and recharging systems, also poses challenges, particularly in balancing environmental considerations with operational needs. Ground infrastructure costs, which are expected to be high, remain largely unexplored but are pivotal for scaling operations effectively.

Addressing system failures, including software and hardware malfunctions, is vital for operational safety, while advanced sensors and perception systems are required to enhance situational awareness. Communication with airspace systems and local aerodromes adds another layer of complexity to system integration. Passenger and cargo drones, each with distinct operational needs, further emphasize the necessity of tailored infrastructure solutions. Scaling UAM operations will require significant investments in both telecommunications and physical infrastructure, including digital systems for airspace integration. While the technological components, such as cameras and LiDAR, are not revolutionary, their meticulous integration into cohesive systems is essential. Without these foundational elements, achieving scalability and operational viability for autonomous UAM will remain a distant goal.					
UAM_E9	German	"Before the whole thing can be commercialized and made usable, it has to be approved."	Regulatory approval is essential for commercialization.	Public Perception & Trust in Automation	Launch into Commercial Operations
UAM_E2	English	"This will likely happen in the next 5-10 years, with a phased approach to introducing autonomous passenger drones into commercial service."	A phased approach will introduce autonomous passenger drones commercially in 5-10 years.	Regulatory Framework & Safety	Launch into Commercial Operations
UAM_E2	English	"By 2025, we'll likely see limited autonomous operations in controlled environments, such as designated corridors."	Initial UAM operations are expected in controlled environments by 2025.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E2	English	"By 2030, widespread adoption in urban areas for short-distance flights could become a reality."	Widespread urban UAM adoption is anticipated by 2030.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E2	English	"By 2035, I expect full integration with existing air traffic management systems, allowing for seamless operations."	Full UAM integration with air traffic systems is expected by 2035.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E3	German	"Regulation isn't ready, and it won't be anytime soon. I'd say definitely not this decade, and even in the 2030s, I find it hard to imagine regulations being in place."	Regulatory frameworks for UAM may not be ready until the 2030s or later.	Regulatory Framework & Safety	Launch into Commercial Operations
UAM_E3	German	"2030 onwards...I can't imagine fully autonomous passenger drones operating within the next 10 years."	Fully autonomous UAM operations are unlikely before 2030.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E3	German	"It's more realistic to gradually introduce autonomous features. […] smaller steps rather than a sudden leap to fully autonomous aircraft in 10 years."	Incremental introduction of autonomous features is more realistic than a sudden transition.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E3	German	"The next big milestone will be having no pilot in the cockpit at all. But I'd say that's at least 10 years away."	Removing pilots entirely is a milestone but likely at least a decade away.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E3	German	"The industry is definitely moving in that direction, though when exactly that will happen is uncertain."	The timeline for autonomous flying technologies remains uncertain despite progress.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E4	English	"It will be difficult to have these ready for full utilization before 2040 or 2045."	Full readiness for autonomous UAM systems is unlikely before 2040–2045.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E4	English	"In the beginning, there will definitely be a remote pilot involved, even when we move towards autonomy. […] Fully autonomous systems without intervention are much further away."	Remote pilots will be necessary initially, as fully autonomous systems are distant.	Impact on Human Roles & Employment	Launch into Commercial Operations
UAM_E4	English	"Autonomous operations should be introduced in phases."	Phased introduction of autonomous operations ensures gradual development.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E4	English	"Gradual progress in resolving these challenges is key to successful deployment."	Gradual resolution of challenges is essential for successful UAM deployment.	Future Outlook & Strategic Vision	Launch into Commercial Operations

UAM_E5	German	"I estimate we're looking at a timeframe of 2035 to 2045 for passenger drone autonomy."	Passenger drone autonomy is expected between 2035 and 2045.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E5	German	"There's also a distinction between autonomous and automated systems […] Automation is relatively easier to achieve and can serve as a steppingstone."	Automation is a steppingstone toward full autonomy.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E5	German	"Initially, we'll likely see automated systems, like remotely piloted drones."	Automated, remotely piloted drones will precede fully autonomous systems.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E5	German	"Currently, only a few companies aim directly for full autonomy, like Wisk. Most others are taking a step-by-step approach."	Few companies aim for full autonomy initially, opting for step-by-step progress.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E5	German	"In this process intermediate steps will be necessary."	Intermediate steps are necessary for achieving autonomy.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E5	German	"Companies shouldn't wait for full autonomy to launch products. They should commercialize intermediate levels to gain real-world experience."	Companies should launch intermediate autonomy levels to gain practical experience.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E5	German	"You can't go from lab development straight to a market-ready product. You need to approach it step by step."	Gradual transition from lab development to commercialization is vital.	Industry Readiness & Technology Advances	Launch into Commercial Operations
UAM_E6	German	"They're all starting with piloted operations for now. Autonomous development is still far off, and there hasn't been much progress yet."	Current focus is on piloted operations, as autonomous development lags behind.	Regulatory Framework & Safety	Launch into Commercial Operations
UAM_E6	German	"Maybe around 2035. But even before that, just getting piloted vehicles approved and in the air is already a significant challenge."	Approving piloted vehicles is a near-term challenge, with autonomy possible by 2035.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E6	German	"The first major step will be transitioning from piloted to semi-automated operations, where one operator oversees multiple vehicles remotely."	Transition to semi-automated operations is a key milestone for UAM.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E7	English	"There are hurdles to overcome, but 2030 is a more reasonable timeline than anything earlier. […] That's when we can expect a certified, revenue-generating aircraft operating without a pilot – not just under an experimental certificate."	Certified, revenue-generating pilotless aircraft are expected around 2030.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E7	English	"Starting with piloted aircraft before moving to autonomy is definitely important because launching a piloted aircraft allows companies to validate their business case."	Starting with piloted aircraft validates business cases before autonomy.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E9	German	"The typical trajectory will likely begin with piloted systems, transition to teleoperation, and eventually move to partial and then full autonomy."	UAM will transition from piloted to full autonomy through incremental steps.	Future Outlook & Strategic Vision	Launch into Commercial Operations
UAM_E9	German	"If progress lags too much, engineers will have developed the technology far beyond what the regulations account for, which creates additional bottlenecks."	Regulatory delays risk mismatches with rapid technological progress.	Regulatory Framework & Safety	Launch into Commercial Operations

Reduction: The commercial introduction of autonomous UAM is expected to occur in phases over the next two decades. Initial operations will likely involve piloted and semi-automated systems, with remote pilots overseeing multiple vehicles. By 2025, limited autonomous operations may begin in controlled environments, such as designated corridors, paving the way for broader urban adoption by 2030. Full integration with air traffic management systems and true autonomy could follow between 2035 and 2045, but significant regulatory and technological hurdles must first be addressed.

<table>
<tr><td colspan="6">Regulatory readiness remains a key challenge, with frameworks for fully autonomous operations unlikely to materialize before the 2030s or even 2040s. Incremental progress—starting with piloted vehicles, transitioning to semi-automated systems, and then achieving full autonomy—will allow companies to validate business models and gain practical experience while building public trust. Automation, as a steppingstone, will precede full autonomy, enabling phased development and gradual scaling.

Despite advancements, the timeline for autonomous systems remains uncertain, with hurdles in regulatory adaptation, technological integration, and public acceptance. Companies must strategically focus on intermediate steps, such as launching automated or teleoperated systems, to navigate these challenges effectively. This step-by-step approach is essential to align technological progress with regulatory and market readiness, ensuring a smooth transition to fully autonomous UAM operations.</td></tr>
<tr><td>UAM_E4</td><td>English</td><td>"Key challenges include defining responsibilities, managing costs, and clarifying accountability in case of accidents. Regulations must establish who has the power to prevent and address issues. […] There needs to be a defined framework for who is responsible at each level – companies, city authorities, or air traffic management."</td><td>Clear responsibility frameworks are crucial for managing UAM challenges.</td><td>Regulatory Framework & Safety</td><td>Liability & Accountability Issues</td></tr>
<tr><td>UAM_E4</td><td>English</td><td>"From a societal perspective, safety is the foundation. Without resolving safety concerns and clarifying responsibilities among stakeholders, collaboration will be difficult."</td><td>Resolving safety and stakeholder responsibilities is key to collaboration.</td><td>Public Perception & Trust in Automation</td><td>Liability & Accountability Issues</td></tr>
<tr><td colspan="6">Reduction: Responsibility and liability allocation in autonomous UAM are critical challenges requiring clear frameworks to define accountability at every level, including companies, city authorities, and air traffic management. Regulations must address who holds the authority to prevent and resolve issues, particularly in the event of accidents. Resolving these questions is essential for fostering collaboration among stakeholders and ensuring the safe deployment of UAM systems.

Safety concerns form the foundation of societal acceptance. Without clarifying responsibilities and ensuring robust safety measures, achieving stakeholder alignment and public trust will remain challenging. Clear, well-defined frameworks are necessary to navigate these complexities and enable successful integration of autonomous UAM into urban environments.</td></tr>
<tr><td>UAM_E2</td><td>English</td><td>"[…] critical aspects to ensure reliability, scalability, and safety. This includes advancements in areas like sensor fusion, edge computing, cybersecurity, human-machine interface, and integration with air traffic management systems. These elements are key to bridging the gap between where we are now and full operational readiness."</td><td>Advanced technologies and integration are key to UAM reliability and safety.</td><td>Industry Readiness & Technology Advances</td><td>Major Challenges</td></tr>
<tr><td>UAM_E3</td><td>German</td><td>"The success of autonomous flying will depend on three key pillars: safety, regulation, and public acceptance. […] Companies in this space need to work on all fronts, not just focus on the technical side."</td><td>Success depends on safety, regulation, and public acceptance, beyond technical development.</td><td>Industry Readiness & Technology Advances</td><td>Major Challenges</td></tr>
<tr><td>UAM_E3</td><td>German</td><td>"These are all interconnected. You won’t get public trust without demonstrating safety, and you won’t get regulations approved without both safety and some level of public support."</td><td>Public trust, safety, and regulations are interconnected and must progress together.</td><td>Public Perception & Trust in Automation</td><td>Major Challenges</td></tr>
<tr><td>UAM_E3</td><td>German</td><td>"You won’t get public trust without demonstrating safety, and you won’t get regulations approved without both safety and some level of public support."</td><td>Public trust and safety demonstrations are prerequisites for regulatory approval, highlighting their interdependence.</td><td>Public Perception & Trust in Automation</td><td>Major Challenges</td></tr>
<tr><td>UAM_E4</td><td>English</td><td>"There are still significant issues. These include cybersecurity, safety, accident prevention, and air traffic management."</td><td>Key challenges for UAM include cybersecurity, safety, accident prevention, and air traffic management.</td><td>Industry Readiness & Technology Advances</td><td>Major Challenges</td></tr>
<tr><td>UAM_E4</td><td>English</td><td>"The main concerns include accidents, conflicts in the air or on the ground, and cybersecurity risks."</td><td>Accidents, air conflicts, and cybersecurity are</td><td>Regulatory Framework & Safety</td><td>Major Challenges</td></tr>
</table>

			major concerns for UAM systems.		
UAM_E5	German	"The key challenges are certification and social acceptance."	Certification and social acceptance are primary hurdles for UAM implementation.	Public Perception & Trust in Automation	Major Challenges
UAM_E7	English	"The reasons for this are primarily regulatory and public perception challenges."	Regulatory and public perception challenges are key barriers to UAM deployment.	Regulatory Framework & Safety	Major Challenges
Reduction: The major challenges in autonomous UAM revolve around achieving reliability, scalability, and safety through advancements in key technologies such as sensor fusion, edge computing, cybersecurity, and integration with air traffic management systems. Success depends on addressing three interconnected pillars: safety, regulation, and public acceptance. Demonstrating safety is essential to build public trust, which in turn is critical for securing regulatory approval. Key concerns include accident prevention, conflicts in the air or on the ground, cybersecurity risks, and certification hurdles. Urban safety, efficient airspace integration, and battery performance also require significant development to enable full operational and commercial deployment. Overcoming regulatory barriers and addressing public perception issues are pivotal for societal acceptance of UAM systems. Ultimately, UAM companies must focus on solving these challenges across technical, regulatory, and social dimensions to bridge the gap between current capabilities and full readiness for urban operations.					
UAM_E10	English	"There are still challenges to overcome for full operational and commercial deployment. Key areas requiring further development include airspace integration, reliability and safety in urban environments, and battery efficiency. […] Solving the most critical barriers relevant to their sector, ranging from technical limitations like sensor fusion and battery efficiency to regulatory frameworks and public acceptance. "	Urban safety, airspace integration, and battery efficiency are key challenges for deployment.	Industry Readiness & Technology Advances	Major Challenges
UAM_E1	English	"One strategy could be using VR to train people and help them adjust to the environment."	Virtual reality training can help familiarize users with autonomous technologies.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E1	English	"Making the air taxi feel larger and allowing passengers to share the experience with others, along with a pilot onboard, could build trust. People feel more secure when they know someone is there to take control if needed. This approach worked with other autonomous mobility technologies."	Larger designs and onboard pilots can build trust in autonomous systems.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E2	English	"The industry needs to educate and inform the public about the benefits and risks."	Public education on benefits and risks is critical for acceptance of UAM technologies.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E2	English	"Demonstrating the safety and reliability of such autonomous systems is also an important aspect."	Proving safety and reliability is essential for building trust in autonomous systems.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E2	English	"Highlighting the environmental benefits of electric and hybrid-electric propulsion systems is also a major argument."	Emphasizing sustainability strengthens support for autonomous UAM systems.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E2	English	"Ongoing research, development, and public engagement initiatives […] aim to build confidence in the technology.	Continuous R&D and public engagement foster trust in autonomous systems.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E3	German	"Influencers play a big role. If high-profile individuals showcase their experiences, it could significantly impact public trust."	Influencers can boost public trust by sharing positive experiences.	Public Perception & Trust in Automation	Public Education & Communication

UAM_E3	German	"It's all about proving safety and reliability. Regulators need data, while the public needs visible examples."	Demonstrating safety through data and examples builds public and regulatory confidence.	Regulatory Framework & Safety	Public Education & Communication
UAM_E4	English	"It's important to understand whether fears are based on misinformation or legitimate issues."	Addressing public fears requires separating misinformation from legitimate concerns.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E4	English	"Providing accurate information is essential. Public education campaigns can help people understand the benefits and safety features of these technologies."	Public education campaigns are vital for understanding and acceptance of UAM.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E4	English	"Sessions to gather feedback from residents can also be helpful to address specific concerns."	Feedback sessions help address specific community concerns about UAM.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E4	English	"Showing concrete benefits – like reduced travel time or improved environmental impact – can improve acceptance."	Highlighting tangible benefits fosters public acceptance of UAM technologies.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E4	English	"It's always important to present the full picture. People need to see both the advantages and any potential impacts."	Presenting a balanced view with detailed, factual information about benefits and trade-offs builds trust and transparency.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E5	German	"It's more about addressing concerns than convincing."	Addressing public concerns is key to acceptance rather than persuasive tactics.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E5	German	"The challenge isn't converting enthusiasts but minimizing opposition from those strictly against it."	Reducing opposition is more critical than engaging enthusiasts for UAM adoption.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E6	German	"Pushback highlights the need for better communication and demonstration of real-world benefits."	Effective communication and demonstrated benefits counter public resistance.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E6	German	"Real-world pilot projects are crucial. They allow people to see and experience the technology firsthand, which can dispel misconceptions and build trust. […] People need to see it in action to truly understand and accept it."	Pilot projects enable firsthand experiences, dispelling misconceptions and building trust.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E7	English	"Marketing and signaling, such as highlighting thousands of safe flight hours, will play a role. However, word-of-mouth and positive reviews will likely have a greater impact."	Positive reviews and word-of-mouth are powerful drivers of public trust.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E9	German	"What can truly drive acceptance is educating the public about what to expect. This education helps alleviate fear of the unknown […] Providing clear information about aspects like vehicle noise levels, sustainability compared to traditional transportation modes like combustion engine cars, and other relevant details is vital."	Educating the public helps reduce fear and build acceptance of new technologies.	Public Perception & Trust in Automation	Public Education & Communication
UAM_E9	German	"Not only informing passengers but also addressing the concerns of people who encounter these vehicles in their daily lives."	Public education must address the wider community, not just passengers.	Public Perception & Trust in Automation	Public Education & Communication

Reduction: Effective communication and public education are essential for fostering acceptance of autonomous UAM technologies. Strategies such as virtual reality training can help familiarize users with the technology, while larger vehicle designs and onboard pilots can enhance passenger trust by offering visible safety measures. Public education campaigns should emphasize the benefits, such as reduced travel time and environmental sustainability, while addressing risks and correcting misinformation. Balanced, transparent information about both advantages and trade-offs is critical to building trust and acceptance.

Demonstrating safety and reliability through pilot projects and real-world examples is a powerful way to dispel misconceptions. Highlighting achievements like thousands of safe flight hours, combined with word-of-mouth and positive reviews, can significantly impact public perception. Engaging high-profile influencers to share their experiences can further boost trust and confidence in the technology.

Public education efforts must go beyond passengers to address the concerns of those who encounter UAM systems in daily life. Community feedback sessions are valuable for understanding and resolving specific issues, while marketing efforts should provide clear, factual information about noise levels, sustainability, and safety features. Ultimately, minimizing opposition and alleviating fear of the unknown through transparent communication, education, and demonstrated benefits will drive public trust and acceptance of autonomous UAM.

UAM_E1	English	"Passenger acceptance is also crucial. People may not want drones hovering near their homes or in public parks."	Resistance to drones in residential areas can hinder public acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"Comfort and confidence are major concerns […] we haven’t studied what levels of acceleration or turbulence are acceptable. This lack of research creates uncertainty around public adoption."	Further research on passenger comfort is needed to boost confidence and adoption.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"When people are surveyed about drones, the sample is often skewed […] you'll mainly attract people who are already interested in drones."	Surveys on drone adoption often overrepresent interested individuals, skewing results.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E2	English	"Building public trust and acceptance is crucial, especially when concerns about safety, noise, and privacy come into play."	Addressing safety, noise, and privacy concerns is vital for building public trust.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E3	German	"Public perception – like in autonomous driving – plays a major role. However, flying is likely even safer – or it already is safer – than driving. But perception matters. More people are afraid of flying than driving, and it will be the same with autonomous flying vehicles."	Public perception often exaggerates risks in aviation compared to driving, despite better safety records.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E3	German	"Safety is always the top priority […] avoiding incidents like a crash is crucial to maintaining public trust. […] If safety isn’t guaranteed, you’ve already lost."	Guaranteeing safety is essential to maintain public trust and avoid setbacks.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E4	English	"Public perception remains another significant issue. Trust in the system, reliability, and utility are all areas that need further exploration. Noise and societal acceptance are challenges."	Trust in reliability and addressing noise concerns are key to societal acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E4	English	"People worry about the presence of drones in their neighborhoods, whether it’s due to noise or privacy concerns."	Noise and privacy concerns deter public acceptance of drones in local areas.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E4	English	"Many people may understand the utility of these technologies but still prefer not to have them close by."	Utility recognition doesn't always translate to acceptance of drones in proximity.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E5	German	"Certification and public perception are the main challenges and closely intertwined. If the public rejects the idea of unpiloted, manned aircraft flying overhead, lawmakers will respond by restricting or prohibiting such operations."	Public rejection influences lawmakers, making acceptance key to regulatory approval.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E5	German	"Public perception is crucial and needs to be proactively managed. If the industry ignores this, it could face long-term resistance."	Proactive management of public perception is essential to avoid long-term resistance.	Public Perception & Trust in Automation	Public Perception & Trust

UAM_E5	German	"For many people, the fear isn't about riding in an eVTOL but having one fly overhead. They feel powerless in such situations."	Fear of overhead drones is a significant barrier to public acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E6	German	"Public perception and acceptance are critical, distinguishing between customer acceptance and broader public acceptance."	Customer and general public acceptance are distinct but equally critical for UAM success.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E6	German	"A single high-profile accident could set the industry back years. That's why starting with less risky use cases, like medical transport, is a smarter approach. You can build trust, refine the technology, and gather operational experience before scaling to passenger transport. With medical transport or cargo, you can gather significant data and demonstrate reliability. [...] Testing these systems in low risk use cases."	Low-risk applications like medical transport can build trust and mitigate setbacks from accidents.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E6	German	"If you show that the system works in practice and is reliable, it's far more convincing than just theoretical promises."	Demonstrating practical reliability builds more trust than theoretical assurances.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E6	German	"Public perception is indeed a significant hurdle. For example, during the Paris Olympics, Volocopter faced massive backlash when they planned to operate within the city."	Backlash against urban drone operations highlights public perception challenges.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E6	German	"Even frequent flyers – a key target group – are skeptical. […] If that's the reaction from an ideal customer base, you can imagine how the broader public feels."	Skepticism from frequent flyers indicates broader public acceptance challenges.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E7	English	"Public perception of automation isn't the primary focus right now. Companies are more concerned with safety and noise. […] While automation is a future goal, companies are prioritizing public trust in the technology and the overall flying experience."	Companies prioritize safety and noise over public perception in early development.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E7	English	"Time in the market is key. Many technologies, like cloud services, were initially distrusted but gained acceptance over time."	Public trust in technologies grows with time and familiarity.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E7	English	"An accident involving one company could create a perception that all autonomous eVTOLs are unsafe. […] The biggest risk, regardless of industry, is a safety event that erodes public trust. Whether it's an accident with a piloted or autonomous aircraft, such incidents could prompt regulators to slow progress significantly."	Industry-wide perception of safety depends on avoiding accidents by any operator.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E8	German	"Acceptance is crucial. People need to feel comfortable with the technology, whether it's noise, privacy concerns, or flying over private property. Technically feasible doesn't necessarily mean it will be accepted. So, I'd place acceptance as the top priority, and the technical requirements stem from that."	Comfort and addressing privacy/noise concerns are vital for public acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E8	German	"Automation itself isn't a major issue for public acceptance. It's more about the aircraft and its perceived impact – noise, safety risks, and environmental concerns."	Perceived impact of aircraft outweighs automation concerns in public acceptance.	Public Perception & Trust in Automation	Public Perception & Trust

UAM_E8	German	"You don't want to face opposition after already achieving certification—like a city council banning operations due to public complaints."	Post-certification public opposition can disrupt operations, underscoring the need for proactive engagement.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E9	German	"You practically have to get people used to the fact that this thing is flying over their heads at all."	Familiarizing people with eVTOLs overhead is key to reducing resistance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E9	German	"It's more a matter of whether the person using it […] trusts the whole thing."	Trust in overall system safety is essential for public acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E9	German	"User-friendliness and affordability are also key factors, but these are basic expectations for any product or service."	Basic expectations like user-friendliness and affordability are critical for adoption.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"People often say they're willing to do something, but their actions don't align, like paying more for sustainable products."	Stated willingness may not align with actual consumer behavior, posing adoption risks.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"The first commercial users of air taxis will react like first-time bungee jumpers. They'll hesitate […] The number of people willing to use the technology at first will be very limited."	Early adoption will face hesitation, requiring efforts to build user trust.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"There has been no comprehensive research on acceptable acceleration levels for passengers. It's an area that still needs exploration."	Passenger comfort factors like acceleration require further research for acceptance.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"Autonomous vehicles often had certified operators onboard who could intervene in emergencies. It's about creating a perception of safety and trust while gradually introducing autonomy."	Onboard certified operators help build trust during the transition to autonomy.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E1	English	"Passengers trust that two pilots are in the cockpit and know what they're doing. That perception – knowing someone is there if something goes wrong – is a significant factor in building trust."	Human oversight is a major factor in passenger trust in autonomous systems.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E2	English	"The industry needs to make sure that autonomous passenger drones are easy to use and accessible to a wide range of people."	Accessibility and ease of use are critical for widespread adoption of drones.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E10	English	"While there is curiosity and excitement about the potential for efficiency and innovation, concerns about safety, noise pollution, privacy, and equitable access remain significant."	Balancing innovation with addressing safety, noise, privacy, and equity is essential.	Public Perception & Trust in Automation	Public Perception & Trust
UAM_E10	English	"The most important factors for public acceptance of UAM include safety, affordability, ease of use, noise levels, and equitable access."	Public acceptance hinges on safety, affordability, and equitable access.	Public Perception & Trust in Automation	Public Perception & Trust

Reduction: Public perception and trust are critical for the adoption of autonomous UAM systems. Concerns about safety, noise, and privacy are among the biggest barriers, particularly in residential areas where drones might be perceived as intrusive. Guaranteeing safety is essential to build trust, as any accidents could significantly erode public confidence and slow regulatory progress. Demonstrating reliability through pilot projects and highlighting tangible benefits, such as reduced travel time and environmental advantages, can help address these concerns.

Familiarity and gradual exposure to the technology, including initiatives like onboard certified operators and real-world demonstrations, are vital for gaining public trust. Noise levels, equitable access, and affordability also play key roles in acceptance, as do addressing fears of overhead drones and potential privacy invasions. Transparent communication, proactive education campaigns, and engaging the public in discussions about benefits and trade-offs can foster trust and mitigate opposition.

Balancing innovation with public acceptance requires the industry to prioritize user comfort, accessibility, and trust-building measures. Early adoption is expected to face hesitation, with initial users requiring reassurance about safety and system reliability. Over time, as the technology becomes more familiar and its safety proven, broader public acceptance is likely to follow. However, the industry must address these challenges early to avoid resistance that could disrupt operations post-certification.					
UAM_E1	English	"In the U.S., there's a 'move fast and fix later' mindset […] but recent scrutiny […] has made them more cautious."	The US regulatory approach balances rapid innovation with increased caution.	Regulatory Framework & Safety	Regional Disparities
UAM_E1	English	"Europe is inherently more risk averse... who takes the blame?' Nobody wants to be responsible; the progress is slow."	Europe's risk-averse regulatory culture slows UAM development.	Regulatory Framework & Safety	Regional Disparities
UAM_E1	English	"China […] scales quickly by leveraging their population...certification processes are more empirical, based on testing […] This allows them to accumulate data and advance quickly."	China's empirical approach enables rapid scaling and progress.	Regulatory Framework & Safety	Regional Disparities
UAM_E1	English	"The Americans and Europeans were far more theoretical […] compliance with scenarios that seemed completely absurd."	Western regulatory approaches often prioritize theoretical over practical scenarios.	Regulatory Framework & Safety	Regional Disparities
UAM_E1	English	"Who will be first to fully certify and deploy these systems? The answer remains unclear. I haven't seen widespread deployment in China or other places where you'd expect to find drones flying around extensively. It's still a very marginal activity."	Widespread deployment of UAM remains limited globally.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E1	English	"The Middle East, particularly projects like NEOM, has shown interest in UAM, but it's too early to say if they'll lead the market. The scale of these projects is ambitious, but they face similar technological and regulatory challenges."	Middle Eastern UAM projects are ambitious but face common industry challenges.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E2	English	"International harmonization will also be crucial to align regulations globally across countries and regions."	Global regulatory harmonization is key for UAM scalability.	Regulatory Framework & Safety	Regional Disparities
UAM_E2	English	"The European Union tends to adopt a more permissive, performance-based regulatory environment."	The EU emphasizes performance-based, flexible regulations for UAM.	Regulatory Framework & Safety	Regional Disparities
UAM_E2	English	"The United States has a more fragmented approach, with the FAA playing a central role in regulating UAM."	The US regulatory landscape for UAM is fragmented.	Regulatory Framework & Safety	Regional Disparities
UAM_E2	English	"In Asia-Pacific countries like Japan and South Korea, there's significant investment in both infrastructure and regulation to support automation."	Asia-Pacific nations invest heavily in infrastructure and regulation for UAM.	Regulatory Framework & Safety	Regional Disparities
UAM_E2	English	"Companies must adapt their strategies to meet the specific requirements of each region while still maintaining a global perspective."	UAM companies must balance regional adaptation with global strategies.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"EASA and the FAA are always the frontrunners. They're the largest, with the most resources, and other countries often follow their lead."	EASA and FAA lead global UAM regulation, influencing other countries.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"Smaller countries often align with one of these major authorities."	Smaller nations follow the regulatory frameworks of EASA or FAA.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"Saudi Arabia has its own, and the UK has the CAA after Brexit. China has the CAAC."	Nations like Saudi Arabia and China maintain independent regulatory bodies.	Regulatory Framework & Safety	Regional Disparities

UAM_E3	German	"In Europe, all countries follow EASA because of agreements like the European Single Sky Agreement. However, individual countries might adjust the implementation slightly to account for local specifics."	EASA regulations are applied across Europe but allow for national customization.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"Under EASA regulations, eVTOLs must meet a safety standard of 10^-9, while the FAA requires 10^-7."	EASA enforces stricter safety standards than FAA for UAM.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"Companies like Joby and Archer certify their aircraft to FAA standards, meaning they cannot operate commercially under EASA rules."	Diverging EASA and FAA standards restrict commercial flexibility for UAM operators.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"The U.S. might be more attractive for companies because of less stringent requirements."	Less stringent U.S. regulations attract UAM companies.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"Even in places like Saudi Arabia or the UAE, safety remains the top priority. They might move faster, but they won't compromise on safety."	Safety is a top priority in emerging UAM markets like Saudi Arabia and UAE.	Regulatory Framework & Safety	Regional Disparities
UAM_E3	German	"The FAA has been very cautious following the Boeing issues. They've been under scrutiny and are unlikely to take risks anytime soon."	The FAA's caution has increased after recent industry scrutiny.	Regulatory Framework & Safety	Regional Disparities
UAM_E4	English	"In Europe and the U.S., the approaches are distinct. The U.S. focuses on operational safety, while Europe emphasizes societal acceptance."	US prioritizes safety; Europe emphasizes public acceptance in UAM regulation.	Regulatory Framework & Safety	Regional Disparities
UAM_E4	English	"This makes it easier for companies to operate in the U.S., where regulations are less strict in some respects."	Less strict US regulations facilitate UAM operations compared to Europe.	Regulatory Framework & Safety	Regional Disparities
UAM_E4	English	"The U.S. is ahead in terms of implementation, but Japan is also making progress, though more aligned with European standards."	US leads UAM implementation; Japan progresses in alignment with Europe.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"What's needed first is a clear roadmap from regulators like EASA or the FAA, outlining how autonomy will be certified and implemented."	Clear regulatory roadmaps are essential for UAM development.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"Certification timelines are heavily influenced by regulatory priorities. Agencies like EASA and the FAA have to balance numerous competing demands."	Certification depends on regulatory priorities and competing demands.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"EASA has positioned itself as a leader in AI and autonomy. They're more advanced in their thinking about autonomy compared to the FAA"	EASA leads in advanced regulatory approaches to AI and autonomy.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"American companies are further ahead in developing autonomous technologies"	US companies lead in autonomous technology development.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"In Europe, progress is slower, though there are exceptions."	Europe's UAM progress is slower but shows exceptions in specific cases.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"China is definitely moving quickly. They already have certified eVTOLs, though these seem to rely more on remote operation than true autonomy."	China advances quickly with remote-controlled eVTOLs.	Industry Readiness & Technology Advances	Regional Disparities
UAM_E5	German	"They appear to use a ground-based network rather than direct data links. […] It's a different methodology but shows they're making progress."	China's ground-based eVTOL communication reflects a unique but progressive approach.	Industry Readiness & Technology Advances	Regional Disparities
UAM_E5	German	"China's strength lies in their speed of implementation. They're not as constrained by bureaucracy."	Rapid implementation in China benefits from minimal bureaucracy.	Regulatory Framework & Safety	Regional Disparities

UAM_E5	German	"The Middle East is also making efforts, especially with substantial financial investments, but they lack deep aviation expertise."	Middle Eastern UAM progress is supported by investment but lacks aviation expertise.	Regulatory Framework & Safety	Regional Disparities
UAM_E5	German	"It's no coincidence there are only two major manufacturers of large passenger aircraft globally – it's incredibly challenging to break into this industry."	High barriers to entry dominate the passenger aircraft manufacturing industry.	Industry Readiness & Technology Advances	Regional Disparities
UAM_E5	German	"eVTOL manufacturers strategically target specific regions where regulations are more favorable and where they see the most profit potential."	UAM manufacturers prioritize regions with favorable regulations and profitability.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E5	German	"Most companies tend to establish themselves in their home markets first."	UAM companies typically start operations in their home markets.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E5	German	"There's often a pull toward the U.S., where funding opportunities are more abundant."	Abundant funding makes the US a preferred market for UAM.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E6	German	"Regions like North America, Europe, Germany, and Asia all have very different public perceptions and regulatory landscapes."	UAM public perception and regulations vary significantly across regions.	Regulatory Framework & Safety	Regional Disparities
UAM_E6	German	"In China […] the lower airspace is highly regulated and controlled by the military, creating significant operational challenges."	Military-controlled lower airspace in China creates UAM regulatory hurdles.	Regulatory Framework & Safety	Regional Disparities
UAM_E6	German	"There should be consistent standards between the U.S. and Europe, at a minimum. Otherwise, manufacturers face fragmented regulations, which is counterproductive for scaling the technology globally."	Fragmented US-Europe regulations hinder global scalability of UAM.	Regulatory Framework & Safety	Regional Disparities
UAM_E6	German	"The U.S. and China are much more open to adopting new technologies. They understand the strategic importance of staying competitive in these areas, and their governments often support development, either directly or indirectly."	The US and China are expected to be the frontrunners in implementing autonomous passenger drones.	Regulatory Framework & Safety	Regional Disparities
UAM_E6	German	"The EU […] tends to be more conservative, prioritizing safety and taking a much slower approach."	EU's conservative stance prioritizes safety but slows UAM progress.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E6	German	"I'm confident that the U.S. and China will lead in implementation."	The US and China are expected to lead UAM implementation globally.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E6	German	"Companies will focus on regions where they can launch and scale most quickly, and the U.S. and China are far more conducive to that."	UAM companies prioritize the U.S. and China for faster launch and scaling.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E7	English	"In the U.S., UK, and Europe, regulators like the FAA and EASA collaborate to align standards. This avoids creating vastly different regulations, which would make global certification challenging."	Regulatory collaboration in the US, UK, and Europe aims to prevent fragmented standards.	Regulatory Framework & Safety	Regional Disparities
UAM_E7	English	"China and those in the Middle East, are more responsive and move faster. […] Japan is also on a fast track for general UAM development."	China, the Middle East, and Japan are progressing rapidly in UAM.	Regulatory Framework & Safety	Regional Disparities
UAM_E7	English	"Companies are obviously taking advantage of that and adjust their strategies to […] regions where civil aviation authorities are more flexible."	UAM companies adapt strategies for regions with flexible aviation regulations.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"There are bilateral agreements between the US and Europe […] but they don't require harmonization	Bilateral agreements lack full harmonization, complicating cross-	Regulatory Framework & Safety	Regional Disparities

		when it comes to drones. […] If a drone is certified in the USA, that doesn't mean it can operate in Europe without additional approvals. There's a clear need for greater harmonization."	region drone certification		
UAM_E8	German	"In Europe, there's already a lot in place that should work, but scalability is the issue. The underlying infrastructure and supply chains aren't as developed or stable as in traditional aviation."	Europe's UAM frameworks are adequate but face scalability challenges due to infrastructure gaps.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"Countries like China and Japan or projects like NEOM tend to take on more risk and have shorter decision-making processes to support alternative pathways."	China, Japan, and NEOM projects embrace risk and fast decisions to accelerate UAM.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"China has several regulatory sandboxes where specific use cases can be tested under unique conditions. Even within China, you'll find three different sandboxes with varying rules."	Regulatory sandboxes in China allow testing of diverse UAM use cases.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"In Europe, the approach has been more top-down - focusing on managing risks upfront. While that results in a comprehensive framework, it can be difficult to find the right mix of rules to move forward effectively."	Europe's top-down regulatory approach creates comprehensive but slower-moving frameworks.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"Other countries seem to achieve quicker results because they address issues iteratively. It's a different mindset—an iterative approach where they start with basic rules, let the technology develop, and address problems as they arise."	Iterative regulatory approaches in some countries lead to faster UAM progress.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"While all EU countries follow EASA regulations, the way they're implemented varies nationally. […] It can even vary at local level […] That's a potential competitive disadvantage for companies operating in the wrong location."	Variations in EASA regulation implementation create competitive disadvantages for UAM companies.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"We're still talking about highly automated systems with a pilot overseeing operations, even in markets like China. […] Fully autonomous operations without human oversight are not yet a reality."	UAM systems remain pilot-supervised; full autonomy is not yet achievable.	Industry Readiness & Technology Advances	Regional Disparities
UAM_E8	German	"I'd expect China to be one of the first markets to implement such systems on a broader scale."	China is likely to lead in broader implementation of autonomous UAM systems.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E8	German	"The gradual, iterative approach – starting small and scaling up – is essential, especially in countries with fewer regulatory barriers."	Gradual, scalable UAM implementation works best in countries with fewer regulations.	Regulatory Framework & Safety	Regional Disparities
UAM_E8	German	"In Europe, progress on mid-risk systems under SAIL 3 and 4 is promising, offering scalable options in the medium term."	Europe's progress on mid-risk UAM systems offers scalability in the medium term.	Regulatory Framework & Safety	Regional Disparities
UAM_E9	German	"In America, the FAA handles this, making the process relatively straightforward. In [...] Europe, EASA manages it, attempting to unify guidance across EU countries and issue common regulatory standards. […] Establishing uniform global standards remains a significant	FAA and EASA aim for standardization, but global uniformity remains a challenge.	Regulatory Framework & Safety	Regional Disparities

		challenge, particularly for operators who want to fly in multiple geographies."			
UAM_E9	German	"The regulatory landscape in Asia, particularly in China, remains less transparent."	China's UAM regulatory environment lacks transparency.	Regulatory Framework & Safety	Regional Disparities
UAM_E9	German	"The EU and the U.S. are progressing rapidly in establishing comprehensive regulatory frameworks to facilitate the safe integration of autonomous passenger drones into their airspaces."	EU and US are advancing regulatory frameworks for safe UAM integration.	Regulatory Framework & Safety	Regional Disparities
UAM_E9	German	"In China, the regulatory environment for passenger drones is more permissive […] allowing companies to advance more rapidly in passenger transport operations."	Permissive regulations in China speed up UAM passenger transport advancements.	Regulatory Framework & Safety	Regional Disparities
UAM_E9	German	"In contrast, European companies such as Volocopter are adhering to the stricter 10^-9 safety standard, which has resulted in a more extended certification process."	Europe's stricter safety standards prolong UAM certification processes.	Regulatory Framework & Safety	Regional Disparities
UAM_E9	German	"If there's less pressure and a longer timeframe […] companies might prefer to avoid the risks associated with operating in China, particularly the higher risk of intellectual property migration. In such cases, they are more likely to remain within European or Western markets."	IP risks in China may lead companies to favor Western markets.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E9	German	"It might be that development in China progresses slowly in terms of size, while the U.S., for instance, could enter the market three years later but experience a much steeper growth curve."	US UAM growth may outpace China despite its head start.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E9	German	"The Middle East [...] From the manufacturer's perspective, such a scenario highlights the challenges of relying on markets like these. While they might promise substantial opportunities, they don't always deliver tangible benefits to companies in a meaningful or sustainable way."	UAM manufacturers face sustainability challenges in Middle Eastern markets.	Future Outlook & Strategic Vision	Regional Disparities
UAM_E10	English	"'China builds, the US invents, and Europe regulates.' This perfectly encapsulates the regional differences in how automation and innovation are approached."	Regional differences define UAM progress: China builds, the US innovates, Europe regulates.	Regulatory Framework & Safety	Regional Disparities

Reduction: The development of autonomous UAM is shaped by distinct Regional Disparities and fragmented regulatory frameworks, which pose both challenges and opportunities. The U.S. embraces a fragmented but innovation-friendly approach, allowing companies to move quickly, though recent scrutiny has introduced greater caution. Europe, in contrast, adopts a more risk-averse, top-down framework focused on safety and societal acceptance, leading to slower progress but more comprehensive standards. China's iterative and empirical methodology enables rapid scaling, supported by regulatory sandboxes for testing diverse use cases, though its military-controlled lower airspace and intellectual property risks create hurdles for international companies.

Global regulatory harmonization is critical for UAM scalability, as differences between regions—such as the stricter safety standards of EASA compared to the FAA—complicate cross-border operations. The U.S. and China lead in implementation due to flexible regulations, faster decision-making, and greater funding opportunities. In Europe, adherence to stringent safety metrics and slower certification processes delays commercialization but ensures a robust foundation for long-term integration. Emerging markets like the Middle East are making substantial investments in ambitious projects, such as NEOM, but their lack of aviation expertise raises concerns about sustainability and practical outcomes.

Iterative approaches seen in China and Japan allow faster progress by addressing regulatory issues incrementally, whereas Europe's comprehensive but rigid frameworks limit short-term adaptability. Despite these differences, regions share common challenges in establishing airspace usage rules, standardizing certifications, and developing infrastructure for scalable operations. Companies must navigate these fragmented frameworks by tailoring their strategies to local regulatory environments while maintaining a global perspective. Achieving international alignment remains a significant hurdle but overcoming it will be essential for unlocking the full potential of UAM across regions.

UAM_E1	English	"Certification is another hurdle. Passenger drones must meet safety standards equivalent to those of traditional aircraft."	Stringent safety standards for certification remain a significant barrier.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E1	English	"Some designs, like Volocopter's, are relatively straightforward. […] But more ambitious projects like Lilium jets face significant hurdles. They promise revolutionary designs but struggle with technical feasibility and certification."	Innovative designs face greater technical and certification challenges.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E1	English	"Manufacturers must decide whether to freeze their designs and pursue certification or continually adopt new technologies."	The choice between certifying stable designs and adopting new tech impacts timelines.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E1	English	"Currently, the standards for autonomous aircraft communication and navigation are not clearly defined."	Lack of clear standards for communication and navigation hinders operational readiness.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E1	English	"The systems in place today operate with their own sets of rules, but there's no consensus on how these systems should interact with each other."	Interoperability challenges between systems hinder cohesive airspace integration.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E1	English	"Making these autonomous systems work is possible, but setting up rules and standards that everyone agrees on is a much slower process."	Technical readiness outpaces the slow development of universal rules and standards.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E2	English	"Navigating complex regulations and meeting certification standards for autonomous operations are significant hurdles."	Regulatory and certification challenges are key obstacles to autonomy adoption.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E2	English	"Regulations need to shift towards being more performance-based, focusing on outcomes rather than prescriptive rules."	Performance-based regulations could better support technological advancements.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E2	English	"A risk-based approach to assess and mitigate risks associated with autonomy will be necessary."	Risk-based approaches are essential to manage and mitigate autonomy-related risks.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E2	English	"Clear certification and validation guidelines specific to autonomous systems need to be established."	Establishing clear certification guidelines is critical for the industry.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E2	English	"Regulations will be relaxed gradually, with incremental steps towards more autonomous operations."	Gradual regulatory relaxation will enable phased autonomy adoption.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E3	German	"Authorities will need enormous amounts of data to prove everything works reliably before allowing such systems."	Extensive data is needed to validate system reliability for regulatory approval.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E3	German	"Despite technically feasible, regulatory challenges are the main hurdle."	Regulatory barriers outweigh technical challenges in achieving operational readiness.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E3	German	"If everything is autonomous, how do decisions get made? How does the regulatory authority certify that the system works reliably in every situation?"	Certifying decision-making reliability is critical for autonomous system approval.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E3	German	"Certifying a single-pilot operation is already a big innovation. […] Single-pilot control is already a milestone."	Single-pilot operation certification marks significant progress in automation.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E3	German	"The training and operations for one pilot instead of two require additional scrutiny by authorities to ensure it's viable."	Single-pilot operations demand intensive scrutiny and specialized training.	Regulatory Framework & Safety	Regulatory & Certification Challenges

UAM_E4	English	"Regulations are very limited. There's no clarity on the number of drones allowed per square kilometer or how these systems will be managed."	Regulations lack clarity on drone density and management in shared airspace.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E4	English	"Cities will need to decide acceptable levels of drone density and usage based on their specific needs."	Local governments will play a key role in setting drone density and usage policies.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E5	German	"For cargo drones, weight is critical. While crashes overpopulated areas can cause damage, over open water, the main concern is environmental pollution."	Weight and environmental safety are key considerations for cargo drone operations.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E5	German	"Autonomous flying isn't about tackling straightforward problems, it's about solving these edge cases comprehensively."	Addressing complex edge cases is vital for autonomous flying system reliability.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E5	German	"Current frameworks don't fully account for autonomous operations."	Frameworks lack provisions for autonomous operations.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E6	German	"Regulatory hurdles are so high that they can't even begin with autonomous technology at this stage. They won't get approvals for fully autonomous operations anytime soon."	High regulatory hurdles block autonomous UAM approvals.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E6	German	"We need a standardized regulatory framework that clearly defines and governs this new form of mobility."	Standardized regulatory frameworks are essential.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E6	German	"There are very limited regulations at the EASA or FAA level, and nothing exists for fully autonomous operations."	EASA and FAA regulations for autonomy are insufficient.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E6	German	"Manufacturers often develop technologies hoping regulators will eventually approve them, but if the rules don't align, it creates significant issues."	Misaligned regulations hinder manufacturers.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E6	German	"Extensive testing is needed. Look at Volocopter – they've conducted over 1,200 test flights with pilots and still haven't reached full certification."	Extensive testing is critical for certification.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E7	English	"Regulations need to address all the corner cases in a way that the FAA or any other civil aviation authority feels is safe."	Regulations must cover edge cases for approval.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E7	English	"Begin with certification for piloted operations. They capitalize on [...] additional payload capacity that comes from not having a pilot, and [...] the reduced costs."	Start with piloted operations before autonomy.	Future Outlook & Strategic Vision	Regulatory & Certification Challenges
UAM_E7	English	"The first step is convincing regulators that autonomy is possible and necessary."	Prove feasibility and need for autonomy to regulators.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E7	English	"Rewriting regulations to be solution-neutral is critical. Instead of requiring a pilot to perform a function, regulations should specify that the function needs to be performed – whether by a pilot or an autonomous system. This requires rethinking rules that were written in an era when pilots were the only option."	Regulations must focus on function, not pilots.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E7	English	"Programs like the FAA's Mosaic initiative are promising steps forward."	FAA's Mosaic program aids autonomy regulation.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E7	English	"Certification for fully autonomous aircraft will require proving the design, manufacturing consistency,	Full autonomy requires proof of reliability and integration.	Regulatory Framework & Safety	Regulatory & Certification Challenges

		and operational integration into existing airspace."			
UAM_E8	German	"Regulations also play a key role. The framework within which these technologies can operate is established but differs greatly across jurisdictions."	Regulatory frameworks vary widely by region.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E8	German	"JARUS started as an informal group of aviation authorities exchanging ideas on unmanned aerial systems. They've developed a risk-based approach, which has been increasingly accepted."	JARUS fosters drone regulation through collaboration	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E8	German	"The European Commission needs to exert more pressure on regulatory bodies and governments to ensure compatibility in regulations."	The European Commission should push for regulatory compatibility.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E8	German	"Currently, we're far from that point. These are high-risk projects, and the fragmented regulatory landscape doesn't make things easier."	Fragmented regulations hinder high-risk projects.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E8	German	"EASA has requirements similar to ETOPS ratings for airliners—basically, ensuring that under all circumstances, the drone has enough range to reach a safe landing spot."	EASA requires safe landing range for drones.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E9	German	"The whole process of regulation and scaling for large-scale use is still a big question mark, which is why there's often the idea of flying it thing in a piloted or teleoperated way at the beginning."	Gradual piloted or teleoperated scaling is necessary.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E9	German	"Currently, no regulation exists for these new flying objects, particularly for passenger transport."	No passenger drone-specific regulations exist.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E9	German	"Regulatory frameworks for autonomous passenger drones are actively being developed, focusing on vehicle classification and airspace integration through Unmanned Traffic Management systems."	Regulations for vehicle classification and airspace use are in progress.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E9	German	"Until we reach that point, there will be technical challenges, material issues, and other obstacles to address. But once the technology is mature and certified for autonomous operation, such concerns should be minimal."	Mature certified tech will ease concerns.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E9	German	"The most critical milestone is regulatory approval. This involves two steps: Creating the regulatory framework to allow approvals and adapting the aircraft to meet these requirements and getting them certified."	Regulatory approval and certification are key.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E9	German	"Regulation is a massive challenge but also where a lot of effort is being concentrated to drive progress in this area."	Regulation is a major challenge and also a key focus area.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E10	English	"Adapting the regulatory framework for autonomous UAM requires a holistic approach that considers the integration of airspace and ground infrastructure into existing urban systems."	Regulations must integrate airspace and ground infrastructure.	Regulatory Framework & Safety	Regulatory & Certification Challenges
UAM_E10	English	"Regulations should focus on defining land-use policies for vertiports, ensuring seamless intermodal connectivity between UAM and other transportation systems, and	Regulations should address vertiports, connectivity, and zoning for efficiency and community impact.	Regulatory Framework & Safety	Regulatory & Certification Challenges

		addressing zoning requirements to balance operational efficiency with community impact."			

Reduction: Regulatory and certification challenges present significant barriers to the development and deployment of autonomous UAM systems. Passenger drones must meet stringent safety standards equivalent to those of traditional aircraft, but the lack of clear standards for communication, navigation, and interoperability hinders operational readiness. Frameworks are fragmented, with varying requirements across regions like EASA and FAA jurisdictions, creating misalignments that complicate certification efforts.

Key challenges include proving reliability for autonomous operations, addressing edge cases, and securing regulatory approval for new technologies. A risk-based, performance-focused approach could better align regulations with technological advancements, emphasizing functional outcomes over prescriptive rules. Extensive testing is essential to validate system safety and reliability, as demonstrated by projects like Volocopter, which conducted over 1,200 test flights yet still awaits full certification.

Incremental adoption, starting with piloted or semi-automated systems, is a practical pathway. This allows manufacturers to validate technologies, build trust, and gradually adapt regulations to accommodate increasing levels of autonomy. Programs like the FAA's Mosaic initiative and JARUS's collaborative efforts are promising steps, but more cohesive global frameworks are necessary to ensure scalability.

Regulations must also integrate airspace management, vehicle classification, and ground infrastructure considerations, such as vertiport zoning and intermodal connectivity. As the industry progresses, rewriting regulations to focus on system functions rather than pilot dependency will be crucial for achieving full autonomy. Despite these hurdles, concentrated efforts to create standardized, solution-neutral frameworks are paving the way for future advancements in autonomous UAM systems.

UAM_E1	English	"The thresholds at which you need redundancy in systems are well established, and the definition of redundancy is also very clear."	Safety redundancy thresholds are well-defined.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E1	English	"Some people argue that since human factors are involved in 80% of aviation accidents, removing human involvement would eliminate 80% of accidents. But that's a biased interpretation. […] they are not the sole cause."	Removing human involvement won't eliminate all accidents.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E1	English	"There are countless instances where human intervention prevented technical issues from escalating into accidents."	Human intervention mitigates technical risks.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E1	English	"Fundamentally, I don't see safety metrics changing. The perception of safety is a different matter."	Safety metrics may remain, but perception varies.	Public Perception & Trust in Automation	Safety & Risk Management
UAM_E2	English	"Safety will be enhanced through redundancy and fail-safes to minimize risks."	Redundancy and fail-safes improve safety.	Industry Readiness & Technology Advances	Safety & Risk Management
UAM_E2	English	"Real-time monitoring is essential to proactively detect and respond to potential safety issues."	Real-time monitoring is vital for safety.	Industry Readiness & Technology Advances	Safety & Risk Management
UAM_E2	English	"The industry needs to showcase the safety features and redundancies built into autonomous systems."	Demonstrating safety features is crucial for trust.	Public Perception & Trust in Automation	Safety & Risk Management
UAM_E3	German	"It's not just about making it work; it must meet extremely high safety standards, requiring rigorous testing."	Rigorous testing ensures high safety standards.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E3	German	"The focus is always on safety first, and then efficiency."	Safety is the top priority over efficiency.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E3	German	"There are already regulations in place for how much battery reserve you need. […] You need alternative landing sites along the route."	Battery reserves and landing sites are regulated.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E3	German	"You want the system to be so safe that parachutes aren't needed. Adding parachutes would imply that the system isn't fully reliable, which could scare passengers."	Systems should eliminate the need for parachutes to build confidence.	Regulatory Framework & Safety	Safety & Risk Management

UAM_E3	German	"The system is designed based on specific assumptions and criteria, with built-in redundancies to ensure that such incidents do not occur."	Systems rely on redundancies to prevent failures.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E4	English	"Safety is always the primary concern—collisions, accidents, or anything that could happen close to their homes."	Safety concerns focus on collisions and residential risks.	Public Perception & Trust in Automation	Safety & Risk Management
UAM_E5	German	"Autonomous aircraft must be capable of landing safely even in a "lost link" scenario – where communication with the ground is lost. The aircraft must rely solely on onboard sensors to ensure a safe landing."	Autonomous systems must ensure safe landings even with communication loss.	Industry Readiness & Technology Advances	Safety & Risk Management
UAM_E5	German	"Another challenge is addressing edge cases – those rare, unpredictable scenarios."	Addressing rare edge cases is crucial for safety.	Industry Readiness & Technology Advances	Safety & Risk Management
UAM_E5	German	"Unlike cars, which can simply stop in case something goes wrong, an eVTOL needs a safe place to land."	eVTOLs require independent safe landing solutions.	Industry Readiness & Technology Advances	Safety & Risk Management
UAM_E5	German	"The system must independently determine a safe landing site without relying on ground-based inputs."	Autonomous systems must identify landing sites independently.	Industry Readiness & Technology Advances	Safety & Risk Management
UAM_E6	German	"There's broad consensus in aviation that more automation generally enhances safety. Humans are often the weakest link in decision-making, especially in complex or high-stress situations."	Automation reduces human error, improving safety.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E6	German	"Redundant systems and real-time monitoring of all parameters are essential to minimize risks."	Redundancy and real-time monitoring mitigate risks.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E7	English	"Control systems and handling. This involves not only writing code to handle corner cases but also developing systems to decide how to handle them. Pilots have extensive handbooks to guide decision-making in emergencies, and these need to be translated into logic."	Automation requires coding corner-case scenarios and emergency protocols.	Future Outlook & Strategic Vision	Safety & Risk Management
UAM_E7	English	"The best way to mitigate this risk is through smart regulation, ensuring companies meet stringent safety standards."	Smart regulations with high standards mitigate risks.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E8	German	"When passengers are involved, safety concerns naturally increase. […] "That's why emergency functions, like automated landing systems, are critical."	Automated emergency systems are critical for passenger safety.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E8	German	"The requirements for emergency systems are much stricter when it comes to regular commercial operations in the future."	Emergency system requirements will be stricter for commercial use.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E8	German	"Perceived safety is as important as actual safety in aviation. That's why it's critical to start with use cases that provide clear societal benefits, like emergency services, to build trust. […] Focus on applications that are less likely to trigger resistance, like emergency services, and develop the technology further from there."	Starting with societal benefit use cases builds trust and minimizes resistance.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E9	German	"These differing safety thresholds significantly impact the pace at which companies can develop and deploy	Safety thresholds impact the development pace of autonomous drones across regions.	Regulatory Framework & Safety	Safety & Risk Management

		autonomous passenger drones in their respective regions."			
UAM_E9	German	"Safety advantage only holds as long as there's no interference between the different systems […] Human error, particularly when some participants are human and others are machines, is a significant challenge during the transition phase."	Transitioning from human to autonomous systems faces challenges from human error.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E9	German	"At a commercially viable level, these vehicles should be as safe as the planes we currently board for holidays."	Autonomous drones must match current airline safety standards.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E9	German	"Safety is undoubtedly the top priority."	Safety is the top priority.	Public Perception & Trust in Automation	Safety & Risk Management
UAM_E10	English	"I firmly believe that safety should always remain the top priority, and the existing regulations should not be relaxed."	Safety must remain the priority, with no relaxation of regulations.	Regulatory Framework & Safety	Safety & Risk Management
UAM_E10	English	"Considering that the UAM concept will operate within urban areas, where the stakes are even higher due to the proximity to dense populations and infrastructure, it may be more appropriate to tighten regulations rather than relax them."	Urban UAM operations may require stricter regulations due to high population density.	Regulatory Framework & Safety	Safety & Risk Management

Reduction: Safety is the paramount concern in autonomous UAM, requiring rigorous standards, redundancy, and fail-safes to minimize risks. Redundancy thresholds and battery reserves, combined with real-time monitoring, ensure system reliability and mitigate technical failures. Autonomous systems must also handle edge cases and independently determine safe landing sites, even in scenarios like communication loss. While automation reduces human error, the transition from human-operated to autonomous systems introduces challenges, particularly during hybrid operational phases.

Demonstrating safety features and conducting extensive testing are critical to gaining public trust and regulatory approval. Emergency systems, such as automated landing functions, are essential, particularly for urban operations where risks to dense populations and infrastructure are higher. Safety standards must align with current aviation benchmarks, ensuring that autonomous UAM achieves the same reliability as traditional aircraft.

Public perception of safety is equally important. Starting with use cases that offer societal benefits, like emergency services, can build trust and reduce resistance. Smart, performance-based regulations should prioritize safety without relaxing existing standards, and urban UAM may require even stricter rules. Ultimately, addressing both actual and perceived safety concerns will be key to the successful adoption of autonomous UAM.

UAM_E3	German	"It's unclear how scalable or certifiable systems of companies like EHang in China are for large-scale operations."	Scalability and certification of UAM systems like EHang remain uncertain.	Industry Readiness & Technology Advances	Scalability Challenges
UAM_E5	German	"They might also need to scale back. Regardless, they're driving innovation in the industry, creating momentum and motivation, which is essential."	Innovation-driven companies like Wisk propel industry momentum despite scalability challenges.	Industry Readiness & Technology Advances	Scalability Challenges
UAM_E6	German	"Automation is essential for scaling up operations […] if you're aiming for mass deployment with hundreds of drones, you need fully automated systems."	Full automation is critical for scaling and managing dense UAM operations.	Industry Readiness & Technology Advances	Scalability Challenges
UAM_E6	German	"Scalability is a key challenge – an area where a lot of development is still needed."	Scalability is a major challenge requiring further development.	Industry Readiness & Technology Advances	Scalability Challenges
UAM_E7	English	"The main challenge is scaling this from a 2-kilogram drone to a 2,400–4,000-kilogram drone, often as a eVTOL aircraft."	Scaling drones to larger eVTOL sizes poses technical challenges.	Industry Readiness & Technology Advances	Scalability Challenges

UAM_E7	English	"Aviation has these technologies, but they need to be improved, made cheaper, and mass-produced."	Aviation technologies need refinement, cost-reduction, and mass production.	Impact on Human Roles & Employment	Scalability Challenges
UAM_E8	German	"Smaller systems with lower risks are good for initial testing because they have fewer barriers and lower investment costs. If they succeed, it builds confidence for scaling up to larger systems."	Testing smaller systems first builds confidence for scaling to larger applications.	Industry Readiness & Technology Advances	Scalability Challenges
UAM_E9	German	"The regulation and certification process is a significant milestone. Once that's in place, the industry can't afford to delay scaling up real-world operations."	Timely scaling after regulatory approval is crucial to stay competitive.	Future Outlook & Strategic Vision	Scalability Challenges

Reduction: Scalability is a critical challenge for autonomous UAM, requiring significant advancements in automation, technology refinement, and regulatory alignment. Full automation is essential for managing dense operations with hundreds of drones, but the scalability and certifiability of systems like those from EHang remain uncertain. Scaling from small drones to larger eVTOLs introduces technical hurdles, including the need for cost-effective production and mass adoption of aviation technologies.

Initial testing with smaller, low-risk systems can build confidence and provide valuable insights for scaling up to larger, more complex operations. However, timely scaling after regulatory approval is essential to maintain competitiveness and capitalize on industry momentum. Companies driving innovation, such as Wisk, play a crucial role in propelling the industry forward, even as they navigate these challenges.

The industry must prioritize automation, cost reduction, and streamlined production processes to achieve large-scale deployment. Overcoming these scalability barriers is vital for realizing the full potential of UAM in commercial and urban applications.

UAM_E1	English	"What we can do technically isn't always what we need to do as a society. […] Some argue we need drones to address specific challenges, others question whether drones are the right solution for broader societal needs."	Technical feasibility doesn't always align with societal needs, prompting debate on drones' roles.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E1	English	"Imagine a drone crashing in a city—it could damage the city's reputation globally. How this aspect of safety is managed and perceived will be a huge challenge for the first market entrants."	Drone accidents in urban areas pose reputational risks for early adopters	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E1	English	"People might welcome a drone delivering their pizza but object to their neighbor's drone hovering outside their balcony. Managing these differing perceptions is crucial. "	Public perception of drones varies by context, requiring careful management.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E2	English	"Current public perception and trust in automation technologies within UAM are mixed. While some people are excited about the potential benefits, others are concerned about safety, noise, and privacy."	UAM trust is mixed, balancing excitement with concerns over safety, noise, and privacy.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E2	English	"Engaging with local communities and addressing concerns around noise, privacy, and other issues is crucial."	Engaging communities and addressing concerns is key for UAM acceptance.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E2	English	"Public acceptance hinges on making the technology easy to use, ensuring safety, and demonstrating clear environmental benefits."	Ease of use, safety, and environmental benefits drive public acceptance.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E3	German	"The customer journey, experience, and convenience also play a role in creating additional value, such as reducing travel time."	Customer experience, convenience, and time savings enhance UAM value.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E3	German	"Being quieter allows flights to operate closer to urban areas. Electrification and environmental friendliness are additional perks."	Quiet, eco-friendly operations support urban UAM acceptance.	Public Perception & Trust in Automation	Social Impact & Acceptance

UAM_E3	German	"Transportation comes down to a trade-off between time and money, with convenience and status also playing roles."	Time, cost, convenience, and status influence transportation choices.	Future Outlook & Strategic Vision	Social Impact & Acceptance
UAM_E6	German	"Sustainability claims don't entirely hold up. We recently conducted analyses, and the results showed that UAM, as currently conceived, isn't as sustainable as advertised."	Current UAM sustainability claims require further validation.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E6	German	"For customers to switch to UAM, there needs to be at least a tenfold improvement in efficiency compared to existing transport options."	Significant efficiency gains are needed for UAM competitiveness.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E6	German	"Time savings are minimal, sometimes even negative, due to the multi-modal nature of UAM trips."	Multi-modal UAM trips may reduce or negate time savings.	Future Outlook & Strategic Vision	Social Impact & Acceptance
UAM_E6	German	"Affordability is an issue – most people won't be able to afford it."	High costs limit UAM accessibility.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E6	German	"Infrastructure projects face significant resistance from local communities and environmental groups."	UAM infrastructure faces public and environmental opposition.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E6	German	"It makes more sense to start with use cases that benefit society as a whole, such as emergency medical transport or disaster relief operations. These use cases could build public acceptance over time."	Societally beneficial use cases can build trust and acceptance for UAM.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E6	German	"If it's seen as a way for the top 10% to skip traffic, it won't go over well."	UAM exclusivity could hinder public acceptance.	Public Perception & Trust in Automation	Social Impact & Acceptance
UAM_E8	German	"Starting with niche applications where the investment and risks are lower allows you to refine the technology and scale later. It's better to perfect the technology in a focused area before addressing larger markets. That way, by the time you enter the commercial market, the technology is mature, and public acceptance is higher."	Focusing on niche, low risk use cases helps refine technology and build public acceptance.	Regulatory Framework & Safety	Social Impact & Acceptance

Reduction: The societal acceptance of autonomous UAM hinges on addressing mixed public perceptions and managing its broader social impacts. While the technology excites some for its potential benefits, concerns over safety, noise, privacy, and environmental sustainability remain significant barriers. Public trust can be fostered by engaging communities, ensuring safety, and demonstrating clear environmental benefits. Ease of use, customer convenience, and time savings further enhance the perceived value of UAM, but high costs and minimal efficiency improvements in multi-modal trips limit its accessibility and appeal.

Early use cases focusing on societal benefits, such as medical transport or disaster relief, can help build trust and acceptance while refining the technology. Starting with niche applications where risks and investments are lower allows the industry to mature before addressing larger markets. However, exclusivity—perceived as serving only the wealthy—could hinder public support, emphasizing the need for equitable solutions.

Quiet, eco-friendly operations and clear communication of sustainability benefits are critical to urban acceptance, though current claims require further validation. Managing resistance to UAM infrastructure from local communities and environmental groups will also be essential. Ultimately, aligning UAM advancements with societal needs and fostering public engagement are key to achieving widespread acceptance and integration.

UAM_E1	English	"Collaboration already exists at some levels, especially with component manufacturers like radar and LiDAR suppliers."	Component manufacturers already collaborate in automation development.	Comparative Analysis Across Industries	Synergy Effects
UAM_E1	English	"There's potential for collaboration in areas like public perception, as seen with the introduction of autonomous metros."	Lessons from industries show that effective public communication can aid adoption in UAM.	Comparative Analysis Across Industries	Synergy Effects

UAM_E1	English	"Cross-referencing and sharing best practices between industries can help address these issues, as the underlying technologies are often similar."	Sharing best practices across industries can streamline adoption by leveraging similarities in technology and regulation.	Comparative Analysis Across Industries	Synergy Effects
UAM_E3	German	"Between traditional aviation and UAM, definitely, as eVTOLs are somewhat in the early stages of development."	Collaboration between traditional aviation and UAM can accelerate eVTOL development.	Comparative Analysis Across Industries	Synergy Effects
UAM_E3	German	"eVTOLs tend to become larger and are likely to evolve in the direction of traditional aviation, with increased payload capacity and range."	eVTOLs are expected to evolve towards traditional aviation capabilities, including larger payloads and extended ranges.	Comparative Analysis Across Industries	Synergy Effects
UAM_E3	German	"It makes sense to share systems rather than develop separate ones since they are flying in the same airspace."	Developing shared systems for airspace management is practical and can enhance efficiency across aviation domains.	Comparative Analysis Across Industries	Synergy Effects
UAM_E3	German	"Automotive might be more distinct, especially in terms of communication infrastructure. On the ground, you can install 5G routers, but in the air, it's a different challenge. eVTOLs are moving much faster."	Collaboration between traditional aviation and UAM can accelerate eVTOL development, especially during early stages.	Comparative Analysis Across Industries	Synergy Effects
UAM_E4	English	"There's potential, but I don't see as much collaboration as I'd expect."	Collaboration opportunities are underutilized.	Comparative Analysis Across Industries	Synergy Effects
UAM_E4	English	"Lessons from autonomous vehicles are being incorporated into air mobility, especially in considering societal aspects earlier in the process."	Societal lessons from autonomous vehicles are applied to air mobility.	Comparative Analysis Across Industries	Synergy Effects
UAM_E4	English	"Communication systems and 5G technologies developed for autonomous vehicles could be adapted for UAM."	5G and communication systems from vehicles could support UAM.	Comparative Analysis Across Industries	Synergy Effects
UAM_E5	German	"Yes, with the automotive or traditional aviation industry, particularly in areas like public acceptance and sensor technology."	Automotive and aviation industries can boost public acceptance and sensors.	Comparative Analysis Across Industries	Synergy Effects
UAM_E5	German	"Automotive advances could make sensors cheaper through economies of scale, which would benefit aviation."	Economies of scale in automotive can reduce aviation sensor costs.	Comparative Analysis Across Industries	Synergy Effects
UAM_E5	German	"There could be some crossover in maintaining connections in challenging environments, like urban canyons. Hence, GPS signal remains a major factor."	Reliable GPS signals are crucial for challenging environments.	Comparative Analysis Across Industries	Synergy Effects
UAM_E6	German	"The automotive industry's advancements in autonomous driving offer valuable insights, particularly in sensors and software development."	Automotive progress in sensors and software benefits UAM.	Comparative Analysis Across Industries	Synergy Effects
UAM_E6	German	"Aviation's expertise in operational safety and systems integration can inform UAM development."	Aviation safety expertise aids UAM implementation.	Comparative Analysis Across Industries	Synergy Effects
UAM_E7	English	"Although traditional fuselage-and-wing aircraft and eVTOLs may appear similar and share some technologies, their underlying business contexts are vastly different. […] The market dynamics and passenger capacities set them apart. […] in today's traditional aviation, autopilot already manages about 90% of flight operations, highlighting the distinct	eVTOLs differ greatly from traditional aircraft in business context and operations.	Comparative Analysis Across Industries	Synergy Effects

		operational differences between the two."			
UAM_E8	German	"The automotive industry is optimized for massive volumes and has different approaches to quality and safety assurance. Aviation, even with drones, operates on smaller scales with higher regulatory hurdles."	Automotive focuses on scale; aviation faces higher regulatory hurdles.	Comparative Analysis Across Industries	Synergy Effects
UAM_E8	German	"While there's overlap in technologies – algorithms, chips, etc. – these differences often prevent seamless collaboration."	Overlapping technologies exist, but industry differences hinder collaboration.	Comparative Analysis Across Industries	Synergy Effects
UAM_E8	German	"It's also a cultural issue. The ways of thinking and working in aviation and automotive are very different."	Cultural differences between industries hinder alignment.	Comparative Analysis Across Industries	Synergy Effects
UAM_E8	German	"Traditional aviation faces its own set of challenges with high regulatory barriers and moves slowly due to these hurdles. That's why smaller systems or light sport aircraft are better starting points for innovation. They're less encumbered by regulatory baggage, allowing for more experimentation and gradual scaling. Nevertheless, bridging the gap between initial funding and full commercialization remains a challenge"	Regulatory barriers slow aviation innovation: smaller systems enable easier scaling.	Comparative Analysis Across Industries	Synergy Effects
UAM_E9	German	"Lightweight materials are a significant focus in the aviation sector because every kilogram saved potentially extends the range. This opens up opportunities for collaboration with the automotive and aerospace industries, as lightweight construction is critical in both fields."	Lightweight construction benefits both aviation and automotive sectors.	Comparative Analysis Across Industries	Synergy Effects
UAM_E9	German	"Networking between aircraft and vehicles, which ties into telecommunications. Mobile service providers and other tech companies will play a role here."	Telecommunications will be critical for aircraft-vehicle networking.	Comparative Analysis Across Industries	Synergy Effects
UAM_E9	German	"Engineering services also offer potential for cross-industry collaboration."	Engineering services support cross-industry collaboration.	Comparative Analysis Across Industries	Synergy Effects
UAM_E9	German	"Standardized components - like semiconductors - are already shared across different fields."	Standardized components like semiconductors are shared across industries.	Comparative Analysis Across Industries	Synergy Effects
UAM_E10	English	"By fostering interdisciplinary collaboration, the project aims to create tailored solutions that advance the readiness and adoption of automation technologies in UAM across various applications."	Interdisciplinary collaboration advances UAM readiness and adoption.	Comparative Analysis Across Industries	Synergy Effects
UAM_E10	English	"Collaboration with industries such as telecommunications, for reliable 5G/6G networks, and energy, for advanced battery technologies and charging infrastructure, can significantly accelerate automation in UAM."	Telecom and energy collaborations drive UAM automation advancements.	Comparative Analysis Across Industries	Synergy Effects
UAM_E10	English	"Industries with competing priorities, such as real estate or traditional transport, could create barriers through zoning conflicts or resistance to market disruption."	Competing industries may create barriers to UAM implementation.	Comparative Analysis Across Industries	Synergy Effects
UAM_E10	English	"Cross-sector partnerships and stakeholder alignment will be critical to overcoming these challenges."	Partnerships and alignment are vital for	Comparative Analysis Across Industries	Synergy Effects

			overcoming UAM challenges.		

Reduction: Cross-industry collaboration is essential for advancing autonomous UAM technologies, yet its full potential remains underutilized. Component manufacturers, such as radar and LiDAR suppliers, already contribute to automation development, and insights from industries like automotive and traditional aviation are being leveraged to enhance UAM adoption. Automotive advances in sensors and software, for instance, provide valuable lessons for cost reduction and scalability, while aviation's expertise in operational safety and systems integration informs UAM development. Similarly, lightweight construction—a focus in both aviation and automotive sectors—offers opportunities for collaboration to optimize range and efficiency.

Shared systems for airspace management are practical given that UAM and traditional aviation operate in the same space, but significant cultural and regulatory differences between industries hinder seamless collaboration. Automotive industries prioritize massive production volumes and rapid innovation, while aviation faces higher regulatory hurdles and slower adaptation cycles. Nevertheless, smaller-scale systems and light sport aircraft provide a testing ground for bridging these differences and accelerating innovation.

Partnerships with telecommunications and energy industries are also crucial. Reliable 5G/6G networks, advanced battery technologies, and charging infrastructure can significantly enhance automation capabilities in UAM. However, competing priorities from sectors like real estate or traditional transport may introduce barriers, such as zoning conflicts or resistance to disruption. Overcoming these challenges requires cross-sector partnerships, stakeholder alignment, and interdisciplinary collaboration to create tailored solutions that advance UAM readiness and adoption while addressing shared technological and regulatory concerns.

UAM_E1	English	"A consistent theme is recognizing the gap between what's technically possible and what's socially or environmentally necessary."	Aligning technical capabilities with societal and environmental needs is essential.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E1	English	"Making autonomous flight is something we can already do. That's totally easy."	Autonomous flight is technically feasible.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E1	English	"Pure flight capability – going up, moving a short distance, and landing – it's technically ready."	Basic autonomous flight capabilities are ready.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E2	English	"The technology has made remarkable progress. I'd say we're about 80% ready for operational and commercial use."	Autonomous passenger drones are 80% operationally ready.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E2	English	"From a technical perspective, we need to ensure system reliability and safety, integrate sensors and systems effectively, and address cybersecurity concerns."	Reliability, system integration, and cybersecurity remain key technical challenges.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E3	German	"Introduce vehicles without human communication, and you'd need completely new technologies."	New communication technologies are required for autonomous vehicles in shared airspace.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E3	German	"Technology is not "ready and available" to the extent that you could build such a system in two years and have it fully operational."	Autonomous UAM is not yet ready for large-scale operational deployment.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E3	German	"Current avionics systems are already heavily automated, like providing directional input while the system calculates the rest."	Existing automated avionics systems serve as a foundation for autonomy.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E3	German	"If you focus on semi-automated systems, you can collect data, test specific features, and release a functioning product sooner."	Semi-automation enables quicker product deployment and data collection.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E3	German	"In today's aircraft, there's already partial automation, and it's steadily increasing."	Partial automation in aviation is steadily advancing.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E5	German	"There's a clear distinction between passenger drones and cargo drones. The requirements differ significantly."	Passenger and cargo drones have distinct requirements.	Industry Readiness & Technology Advances	Technological Readiness

UAM_E5	German	"Some argue aviation could be even easier to automate due to fewer players in the air."	Aviation automation may be simpler due to fewer variables than ground transport.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E5	German	"Each sensor has limitations […] This highlights the complexity of air travel."	Sensor limitations underscore the complexity of autonomous air travel.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E5	German	"Another issue is the conflation of autonomy with AI."	Distinguishing autonomy from AI is essential for clear frameworks.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E5	German	"AI will play a critical role. Solving AI-related challenges will pave the way for autonomy."	Addressing AI challenges is key to achieving autonomy.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E6	German	"It's still in the very early stages – I would even say it's practically non-existent in UAM."	UAM autonomy is in its infancy.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E7	English	"Autonomous passenger drones are definitely a possibility, and the technical roadmap exists. […] The ability for drones to fly autonomously already exists."	Autonomous passenger drones are feasible with an established roadmap.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E7	English	"Many regard this as somewhat easier than ground transport. There are fewer corner cases, it's more predictable, and there's an existing air traffic control system."	Aviation's predictability makes automation easier compared to ground transport.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E8	German	"Automation is already very advanced in some areas. Whether it's package delivery, mapping, or military applications, the mission determines the regulatory box you fall into and the corresponding requirements."	Automation is advanced in many areas, but regulations vary by mission.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E8	German	"For most smaller systems, there's no need for manual low-level control anymore. Pure passenger drones, however, are in a completely different category."	Passenger drones require distinct handling compared to smaller autonomous systems.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E8	German	"The fact that these aircraft are highly automated means operational requirements are increasingly integrated into the design."	Automation requires integrating operational requirements into design from the start.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E8	German	"For drones, it's about real-time data updates, constant analysis, and ensuring reserves under all conditions, like unexpected winds or temperature changes."	Drones rely on real-time data and reserves for safety and efficiency.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E8	German	"Innovations like lightweight materials, fuel efficiency, and operational durability are remarkable achievements. But they highlight just how challenging it is to bring new concepts like UAM to market."	Innovations highlight challenges in bringing UAM to market.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E9	German	"We are relatively far along. […] Fully autonomous vehicles with sensors flying in and out of everything, with no interference."	Autonomous vehicles are advanced but not fully interference-free.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E9	German	"What's always needed is the initial trigger from the outside, so that the flight is started. You have to feed in the data."	External triggers and data inputs are essential to start autonomous flights.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E9	German	"Intellectual property is the currency in this industry, and managing its protection is critical to strategic decision-making."	IP management is crucial in the UAM industry.	Future Outlook & Strategic Vision	Technological Readiness

UAM_E9	German	"If the systems are active and approved to the extent that they meet the defined standards, autonomy is likely safer than human operation."	Autonomy can surpass human safety once standards are met.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E9	German	"Car batteries and aircraft batteries are both in the realm of electrification, but the energy density requirements for flying objects are far greater than for cars. […] Aircraft batteries face high peak loads over short periods, especially during takeoff."	Aircraft require higher energy density than cars, making battery technology vital.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E10	English	"The technology behind autonomous (passenger) drones has made significant progress in recent years, particularly in areas such as autonomous navigation, sensor fusion, and artificial intelligence algorithms."	Advances in navigation, sensor fusion, and AI drive drone technology forward.	Industry Readiness & Technology Advances	Technological Readiness
UAM_E10	English	"While some technologies have been successfully tested in prototype and pilot projects, making them suitable for niche use cases"	Tested technologies are suitable for niche applications but not broad deployment.	Industry Readiness & Technology Advances	Technological Readiness

Reduction: Autonomous UAM technologies have made significant progress, with basic flight capabilities and autonomous navigation already feasible. Current systems, including advanced avionics, automation, and sensor integration, form a strong foundation, but challenges in reliability, cybersecurity, and energy density remain. While semi-automated systems allow for quicker deployment and data collection, fully autonomous passenger drones are still in their infancy, requiring further technological and regulatory advancements for large-scale implementation.

Real-time data processing, sensor fusion, and AI are critical areas of development, as these innovations ensure safe and efficient operations. Lightweight materials, operational durability, and high-density batteries are also essential for overcoming the unique demands of flight. Although autonomy in aviation may appear simpler than ground transport due to fewer variables, the complexity of air travel, including edge cases and regulatory variations, adds significant challenges.

The roadmap for achieving fully autonomous passenger drones exists, but niche applications, such as cargo or emergency services, are currently more viable. Further advancements in AI, integration of operational requirements, and rigorous testing are necessary to bridge the gap between prototype successes and commercial readiness. Ultimately, aligning technical capabilities with societal and regulatory needs will be key to realizing the full potential of autonomous UAM.

A.4 Survey on Public Perception

A.4.1 Questions

Comment: Questions marked as "UW" were asked only to participants who were unwilling (not willing at all, rather not willing, or neutral), and "W" indicates questions asked to participants who were willing (rather willing or very willing) to use the respective mode of transport.

Category	Abbreviation	Question
General	G-Q1	How tech-savvy do you consider yourself?
Autonomous Vehicle	AV-Q1	How familiar are you with autonomous driving?
	AV-Q2	How willing are you to take a ride in a fully autonomous vehicle?
	AV-Q3	How important are the following factors in your decision not to take a ride in a fully autonomous vehicle?
	AV-Q4 UW	How important are the following factors in convincing you to take a ride in a fully autonomous vehicle in the future?
	AV-Q4 W	How important are the following factors in your consideration to ride in a fully autonomous vehicle?
	AV-Q5 UW	How important are the following benefits in influencing your choice to take a ride in a fully autonomous vehicle in the future?
	AV-Q5 W	How important are the following benefits in influencing your choice to take a ride in a fully autonomous vehicle?
	AV-Q6 UW	How important are the following benefits in influencing your choice to take a ride in a fully autonomous vehicle in the future?
	AV-Q6 W	In what types of travel scenarios would you prefer taking a ride in a fully autonomous vehicle?
Single Pilot Operations	SIPO-Q1	How familiar are you with single-pilot operations?
	SIPO-Q2	How willing are you to fly on an aircraft operated by a single pilot?
	SIPO-Q3	How important are the following factors in your decision not to fly on a single-pilot operated aircraft?
	SIPO-Q4 UW	How important are the following factors in convincing you to fly on a single-pilot operated aircraft in the future?
	SIPO-Q4 W	How important are the following factors in your consideration to fly on a single-pilot operated aircraft?
	SIPO-Q5 UW	How important are the following benefits in influencing your choice to fly on a single-pilot operated aircraft in the future?
	SIPO-Q5 W	How important are the following benefits in influencing your choice to fly on a single-pilot operated aircraft?
	SIPO-Q6 UW	How important are the following benefits in influencing your choice to fly on a single-pilot operated aircraft in the future?
	SIPO-Q6 W	In what types of travel scenarios would you prefer flying on a single-pilot operated aircraft?
Urban Air Mobility	UAM-Q1	How familiar are you with autonomous Urban Air Mobility (UAM)?
	UAM-Q2	How willing are you to fly in an autonomous passenger drone?
	UAM-Q3	How important are the following factors in your decision not to fly in an autonomous passenger drone?
	UAM-Q4 UW	How important are the following factors in convincing you to fly in an autonomous passenger drone in the future?

	UAM-Q4 W	How important are the following factors in your consideration to fly in an autonomous passenger drone?
	UAM-Q5 UW	How important are the following benefits in influencing your choice to fly in an autonomous passenger drone in the future?
	UAM-Q5 W	How important are the following benefits in influencing your choice to fly in an autonomous passenger drone?
	UAM-Q6 UW	If you were to consider flying in an autonomous passenger drone in the future, what types of travel scenarios would you prefer?
	UAM-Q6 W	In what types of travel scenarios would you prefer flying in an autonomous passenger drone?
General	G-Q2	Which of these modes of transport do you trust most?
Demographics	D-Q1	What is your age?
	D-Q2	What is your gender?
	D-Q3	What is your nationality?
	D-Q4	What is your current employment status?
	D-Q5	What is your academic / occupational category?
	D-Q6	What is your highest level of education?
	D-Q7	What is your annual income?

A.4.2 Sequence of Questions

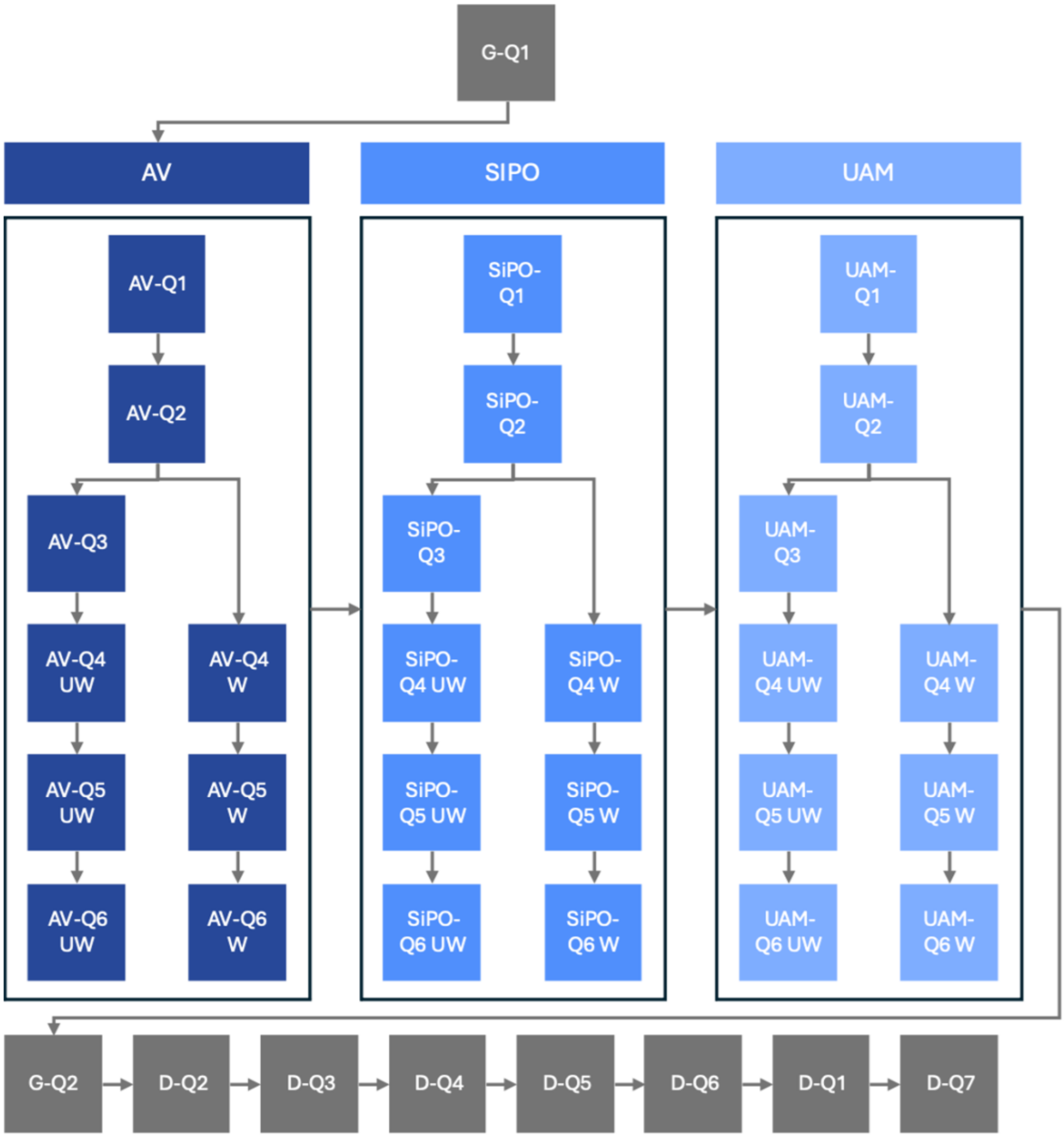


Figure 3: Sequence of survey questions

A.4.3 Result Visualization

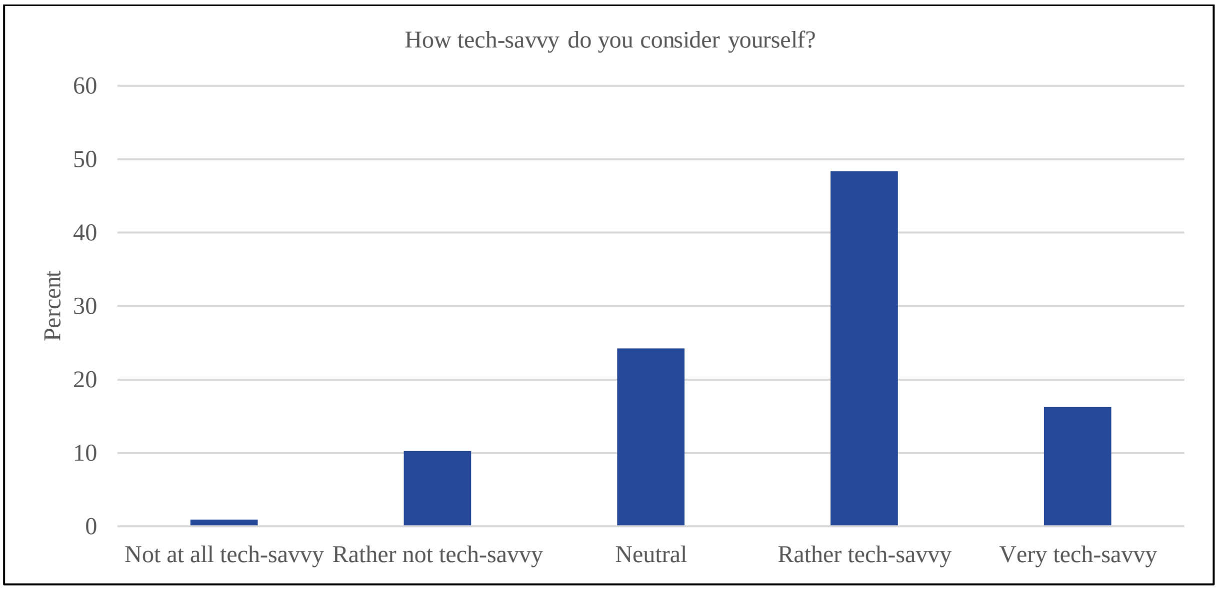


Chart 3: G-Q1

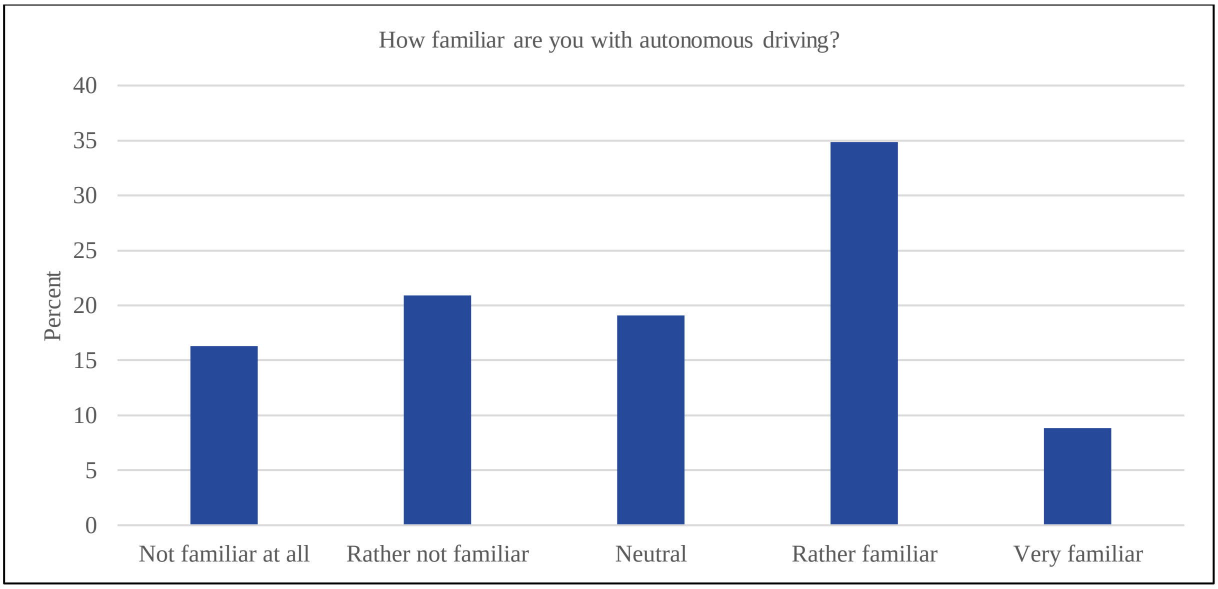


Chart 4: AV-Q1

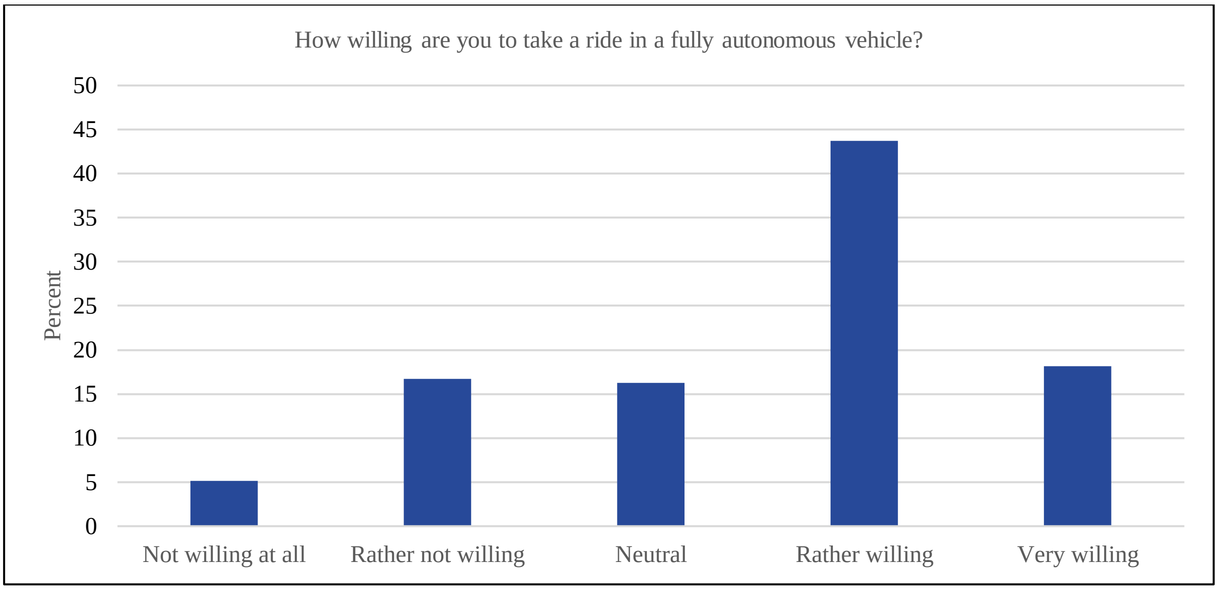


Chart 5: AV-Q2

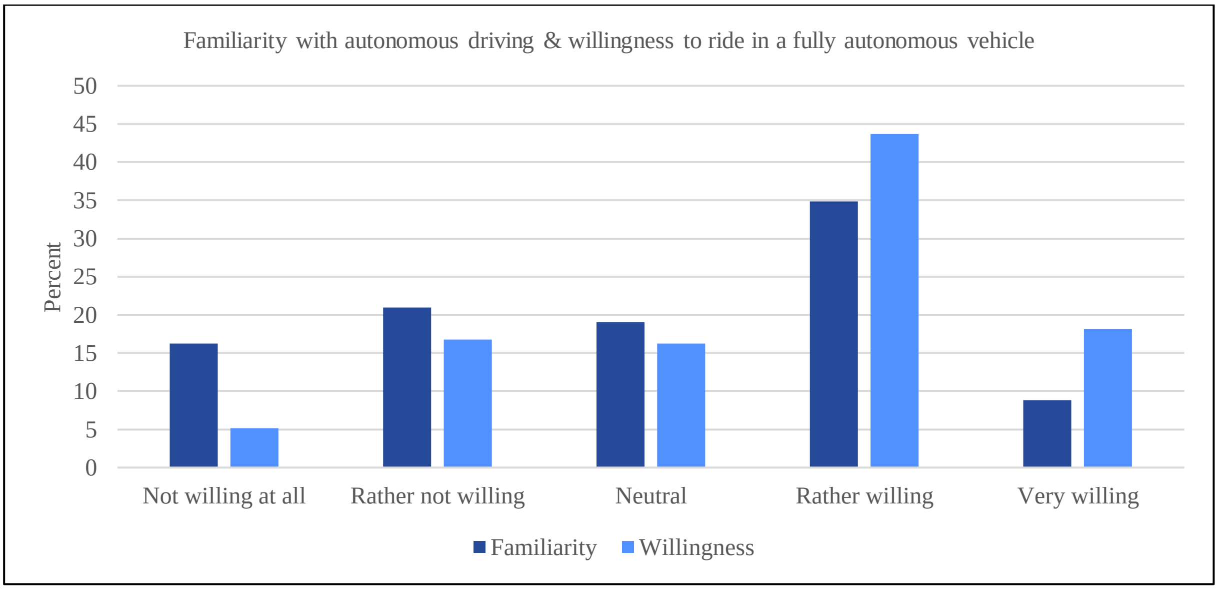


Chart 6: AV-Q1 &Q2

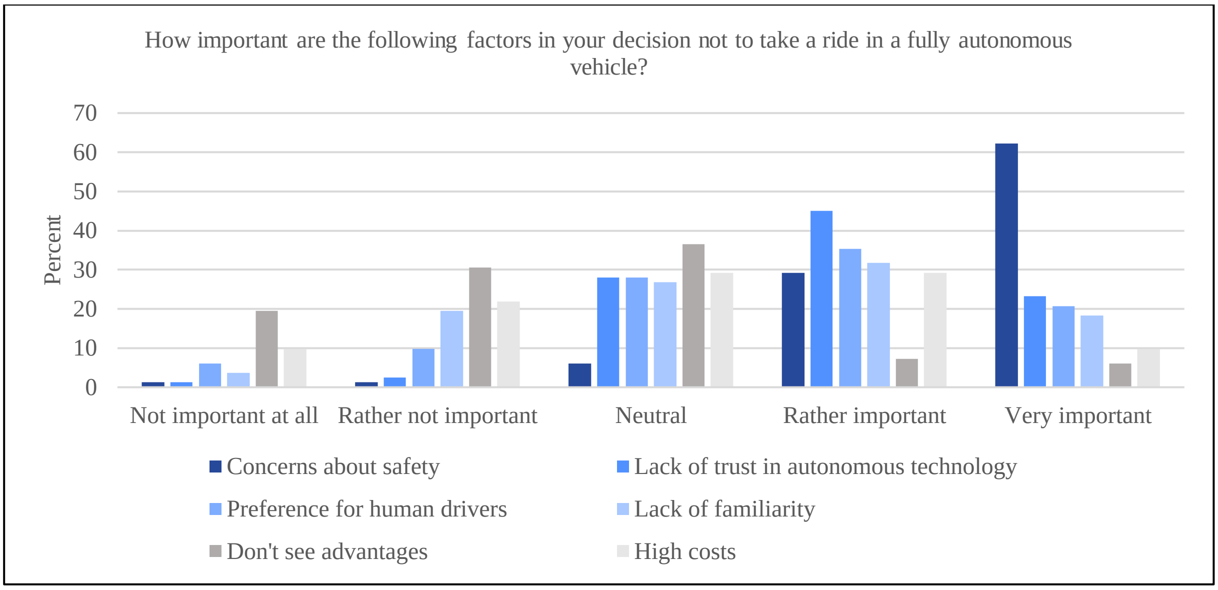


Chart 7: AV-Q3

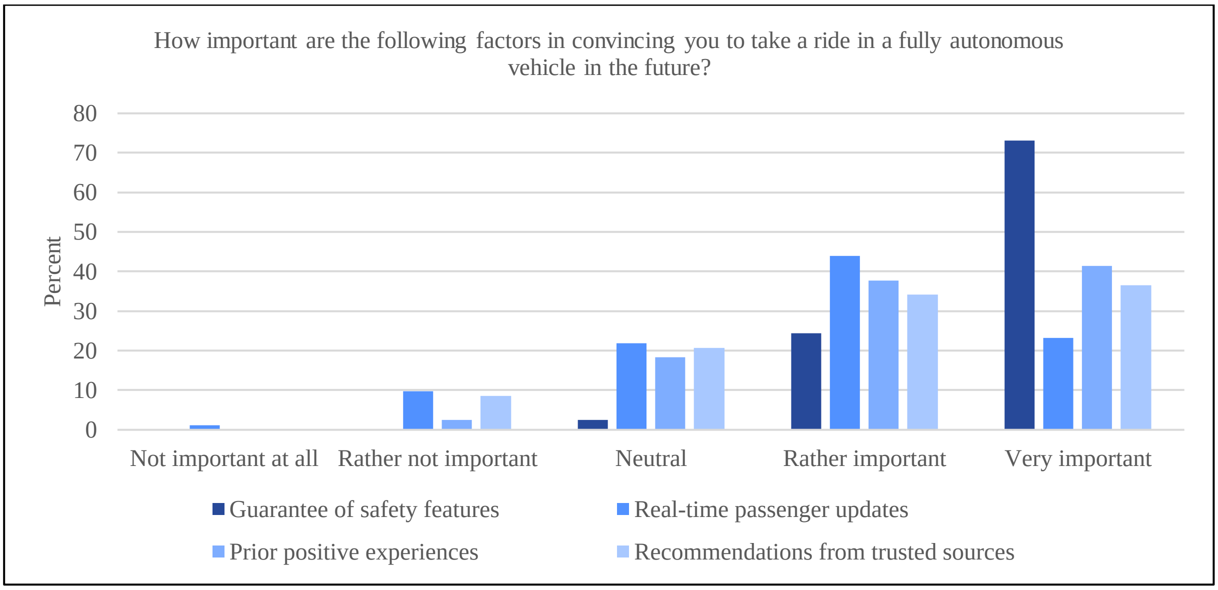


Chart 8: AV-Q4 UW

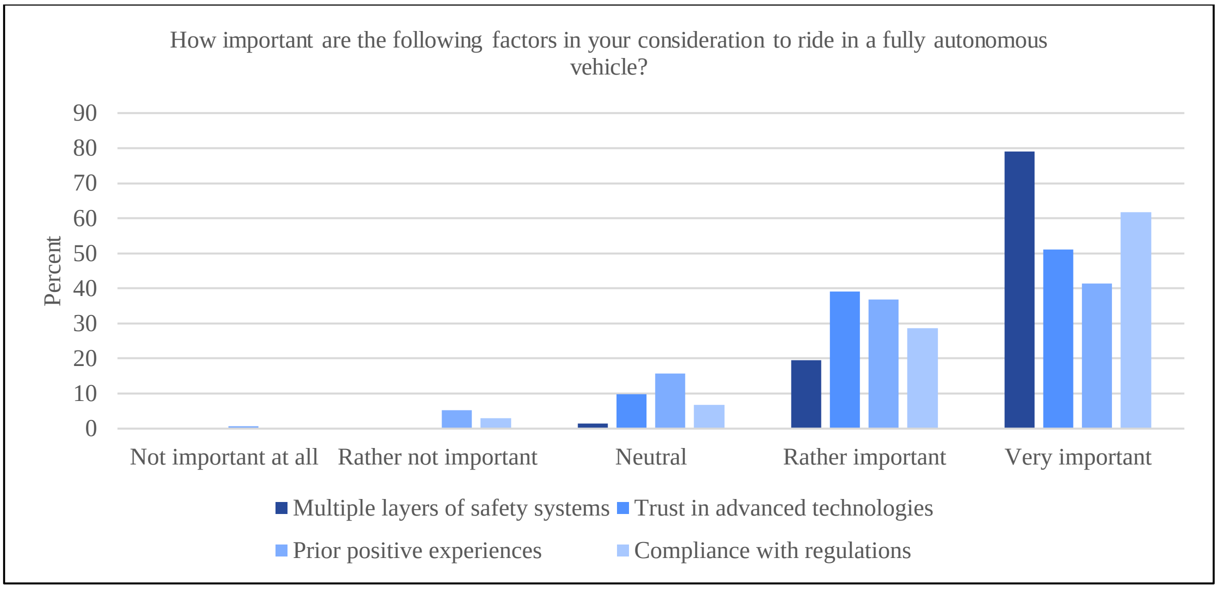


Chart 9: AV-Q4 W

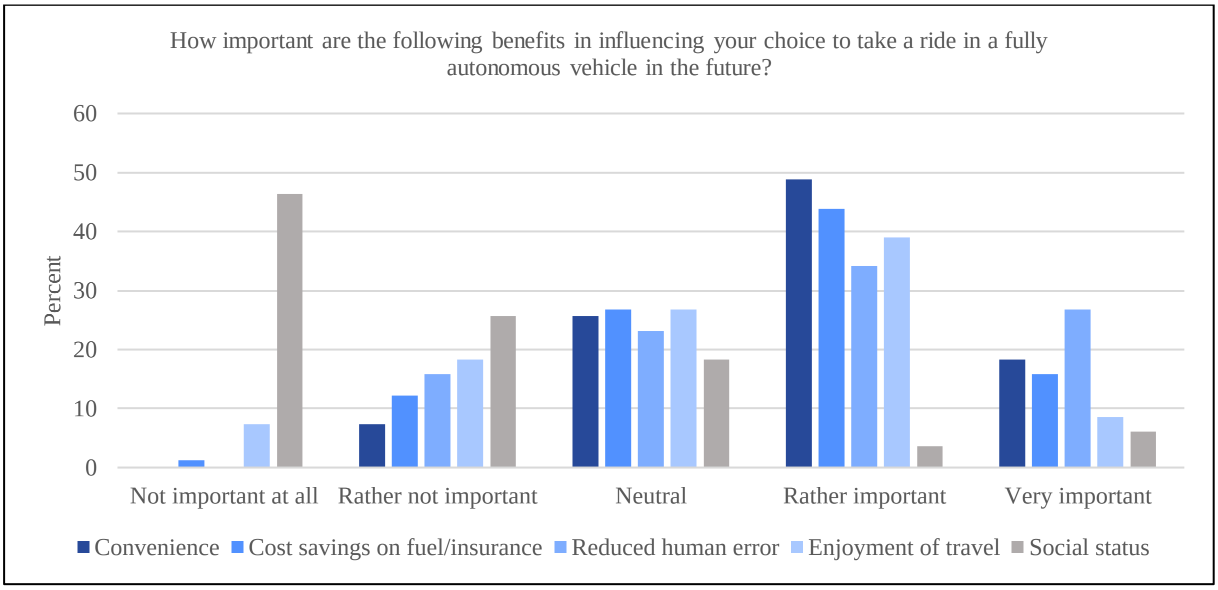


Chart 10: AV-Q5 UW

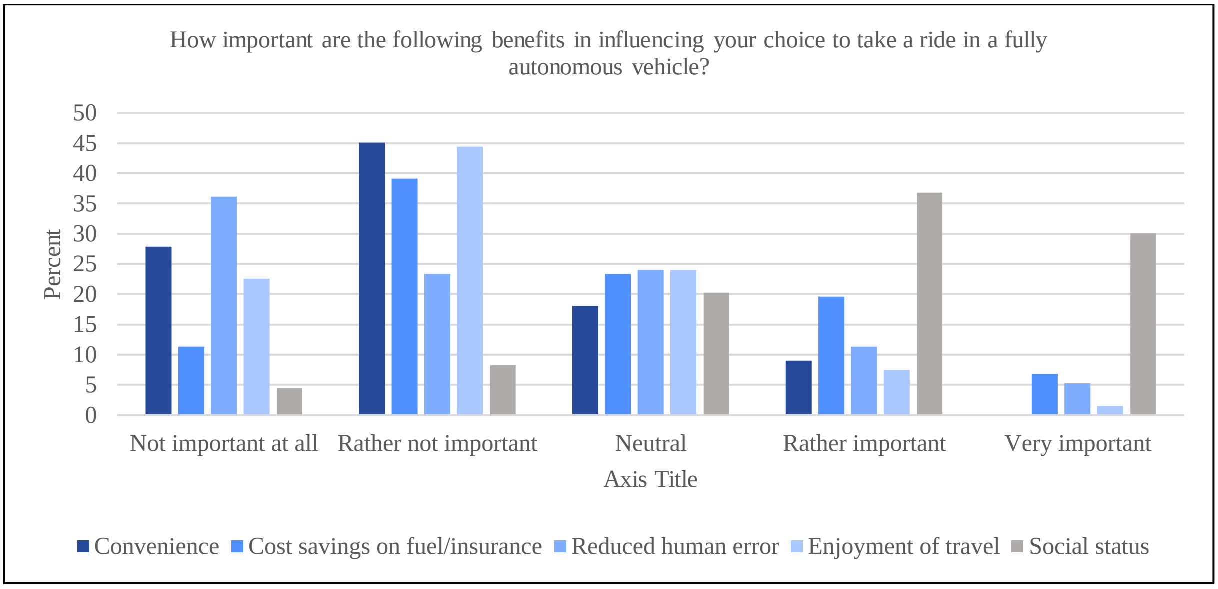


Chart 11: AV-Q5 W

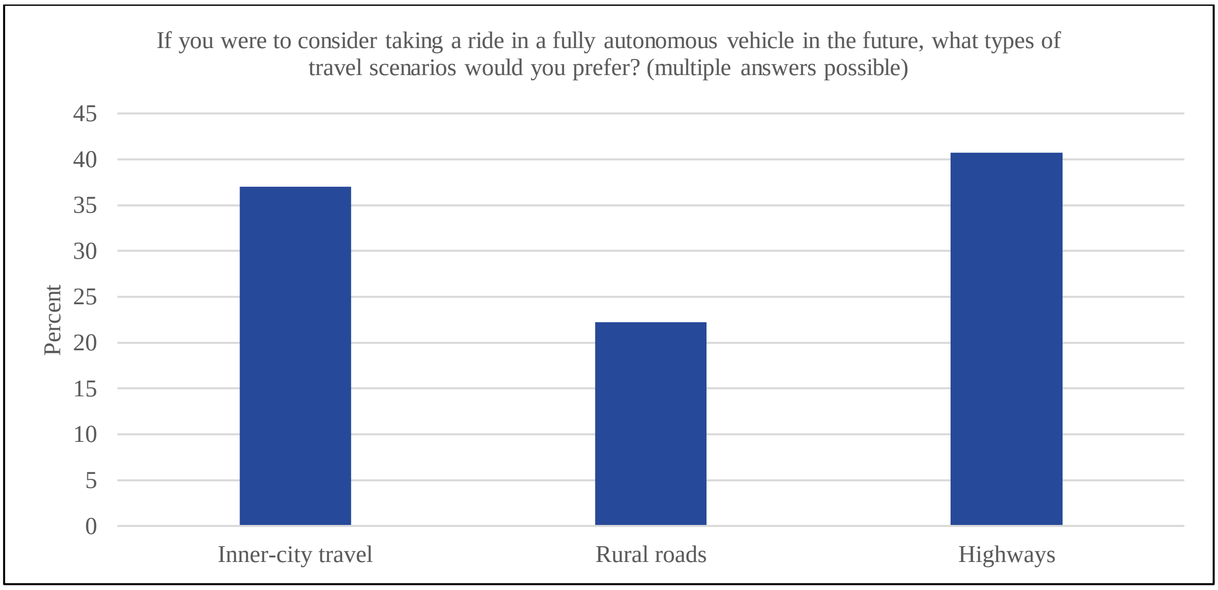


Chart 12: AV-Q6 UW

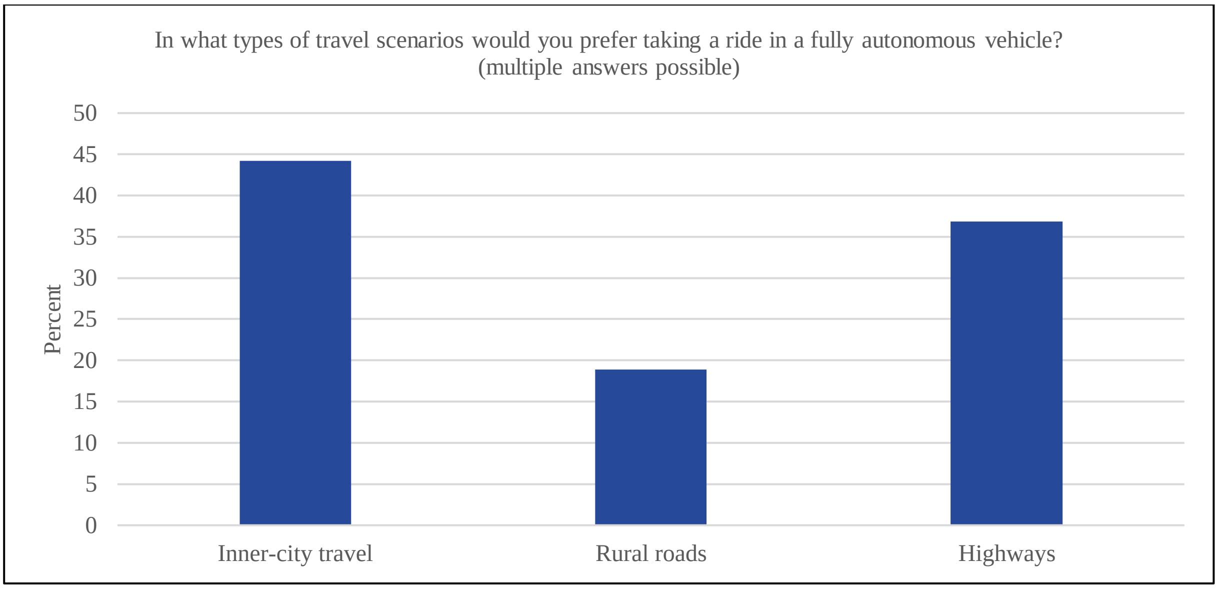


Chart 13: AV-Q6 W

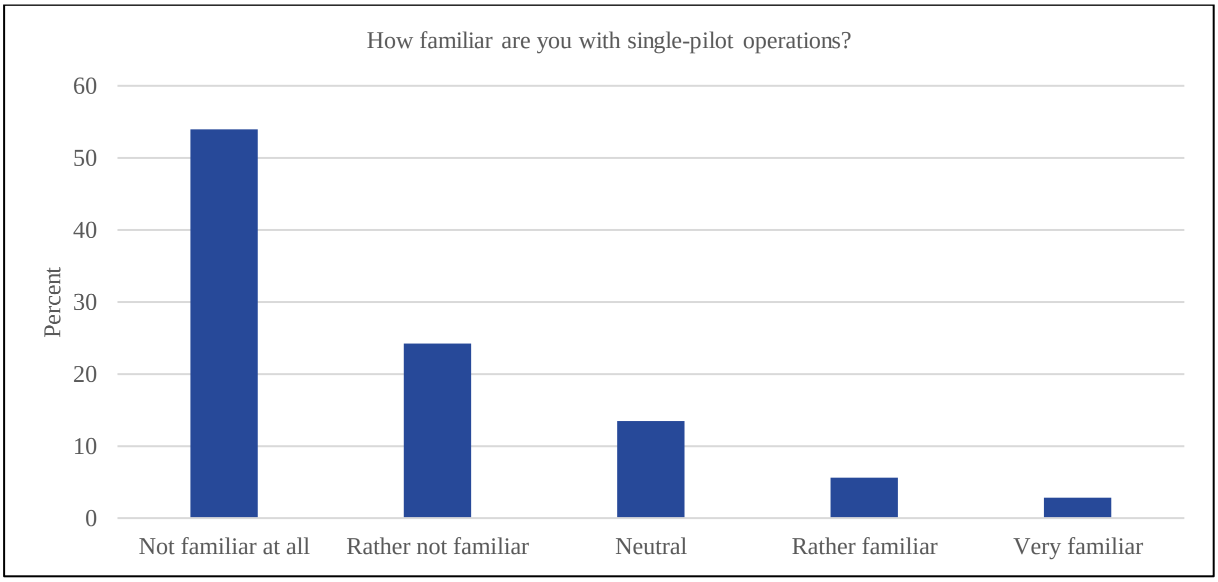


Chart 14: SiPO-Q1

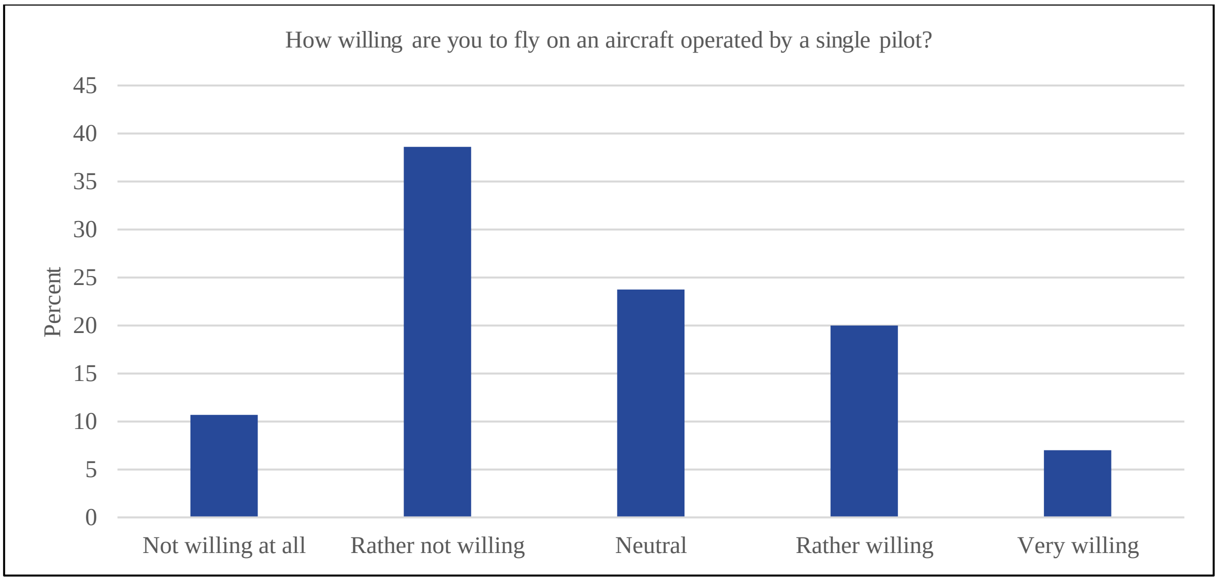


Chart 15: SiPO-Q2

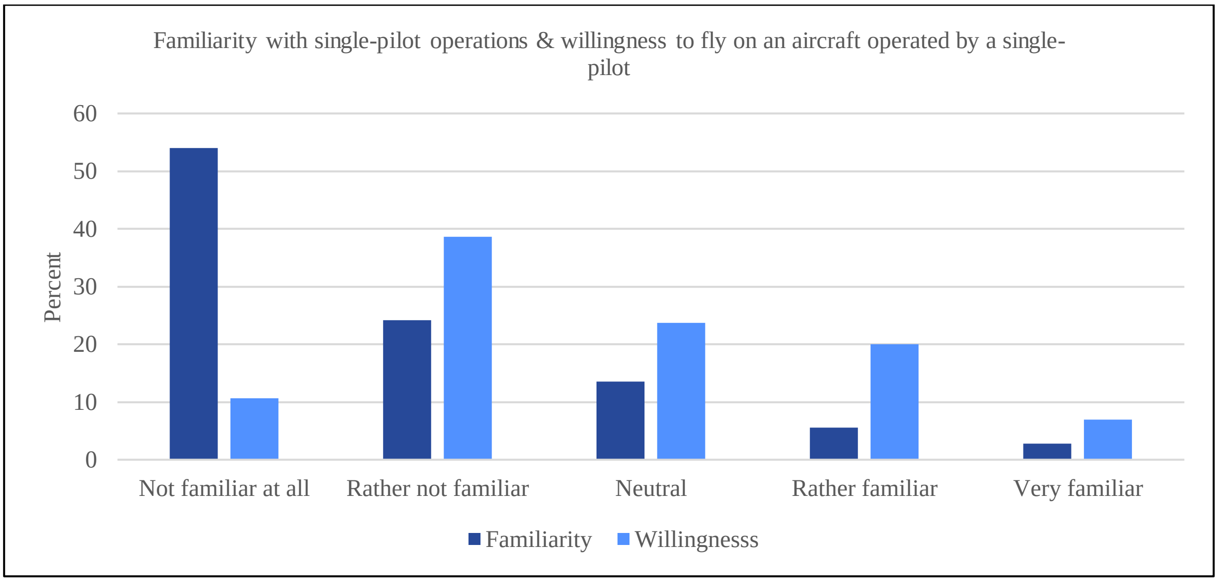


Chart 16: SiPO-Q1 & Q2

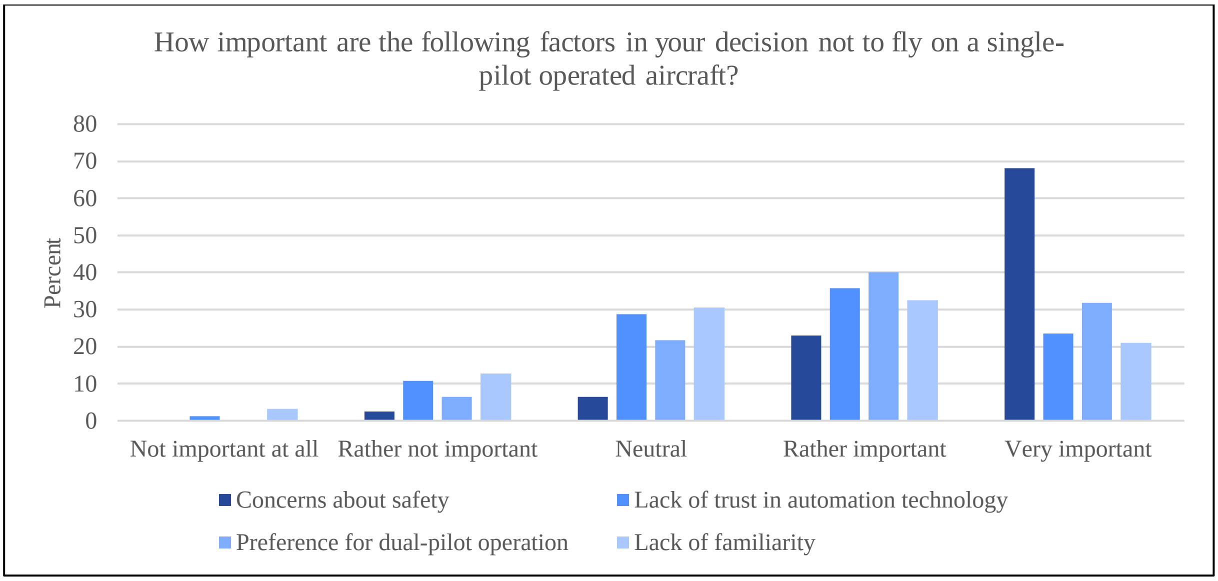
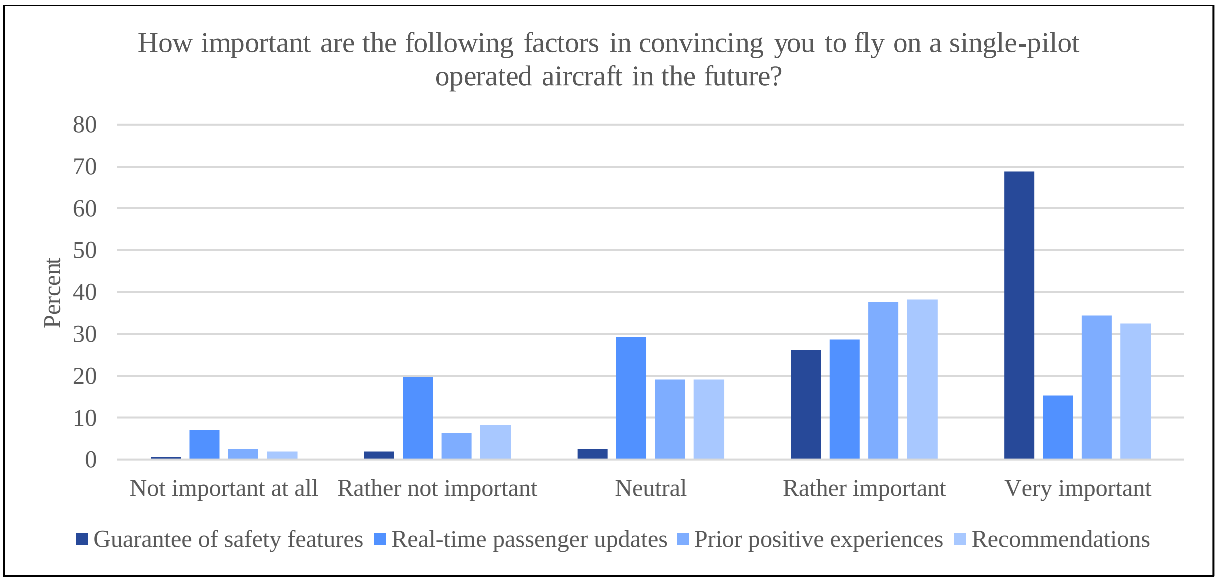


Chart 17: SiPO-Q3



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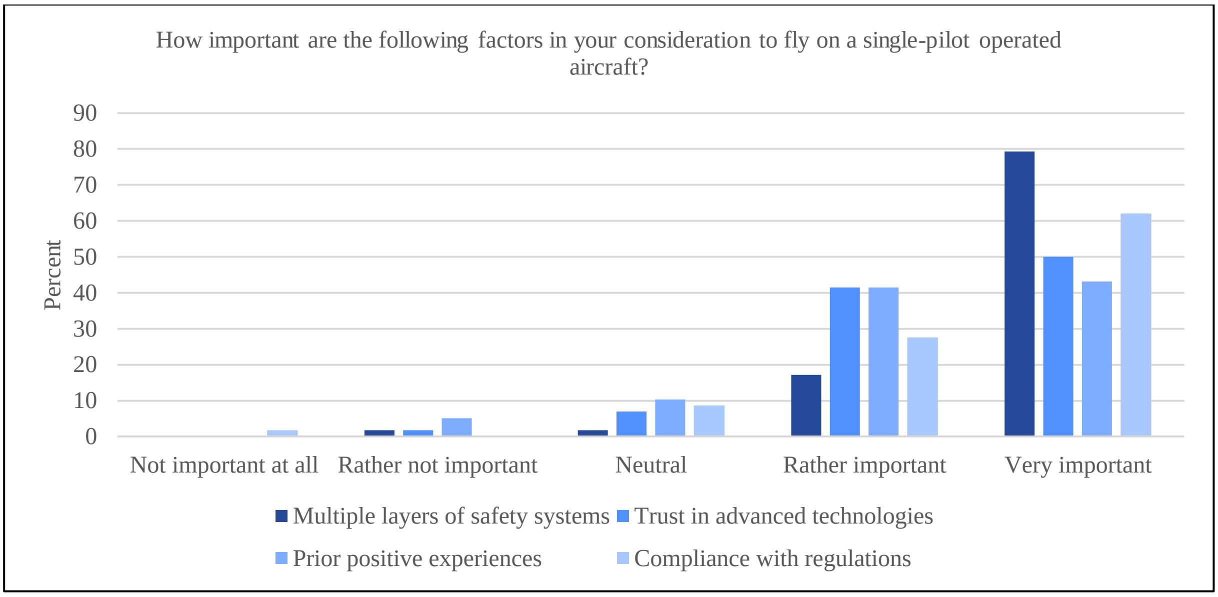


Chart 19: SiPO-Q4 W

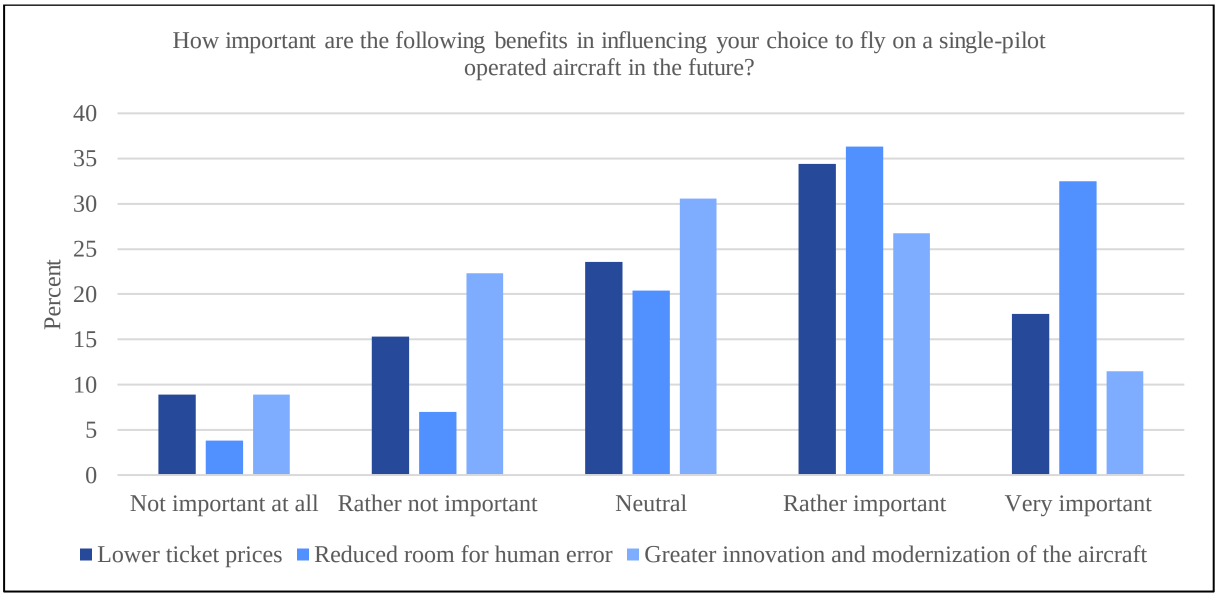


Chart 20: SiPO-Q5 UW

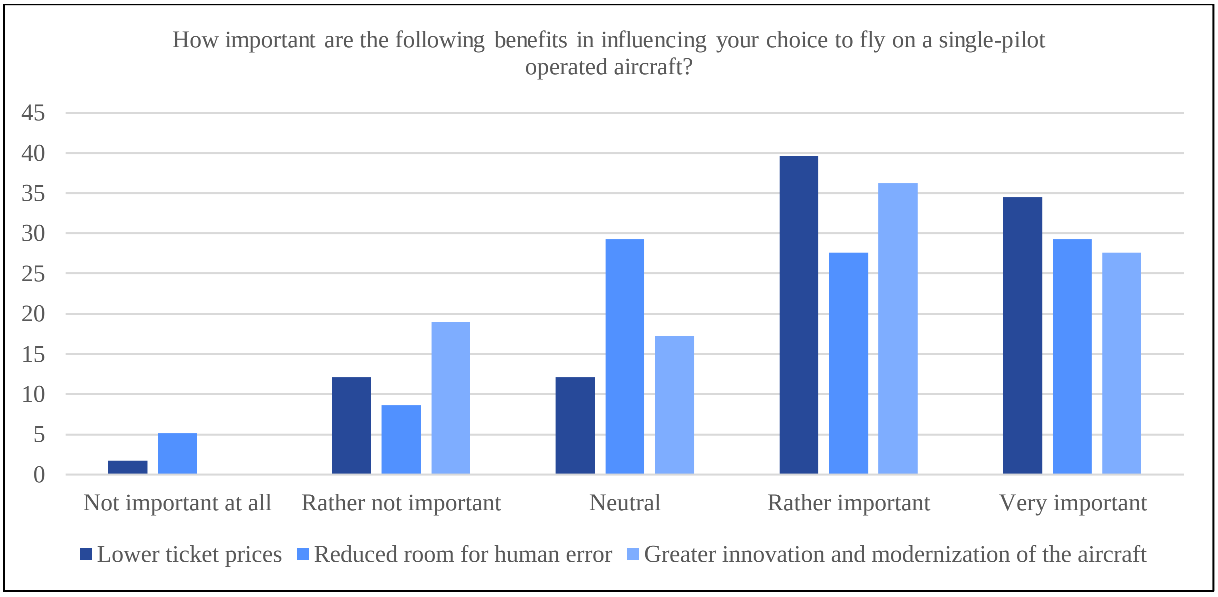


Chart 21: SiPO-Q5 W

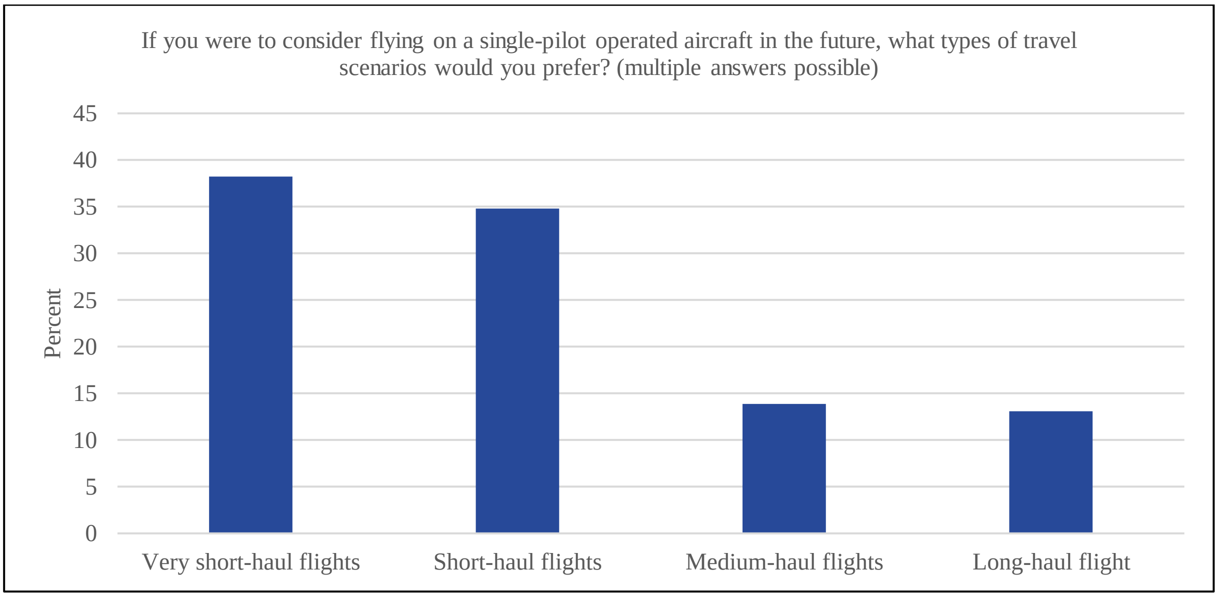


Chart 22: SiPO-Q6 UW

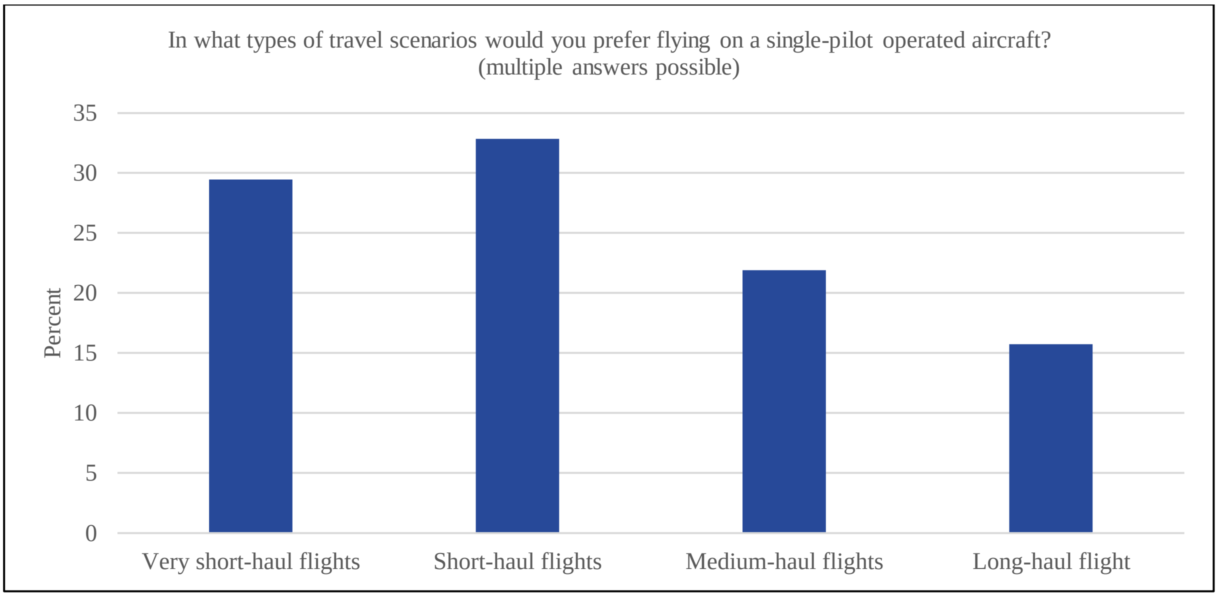


Chart 23: SiPO-Q6 W

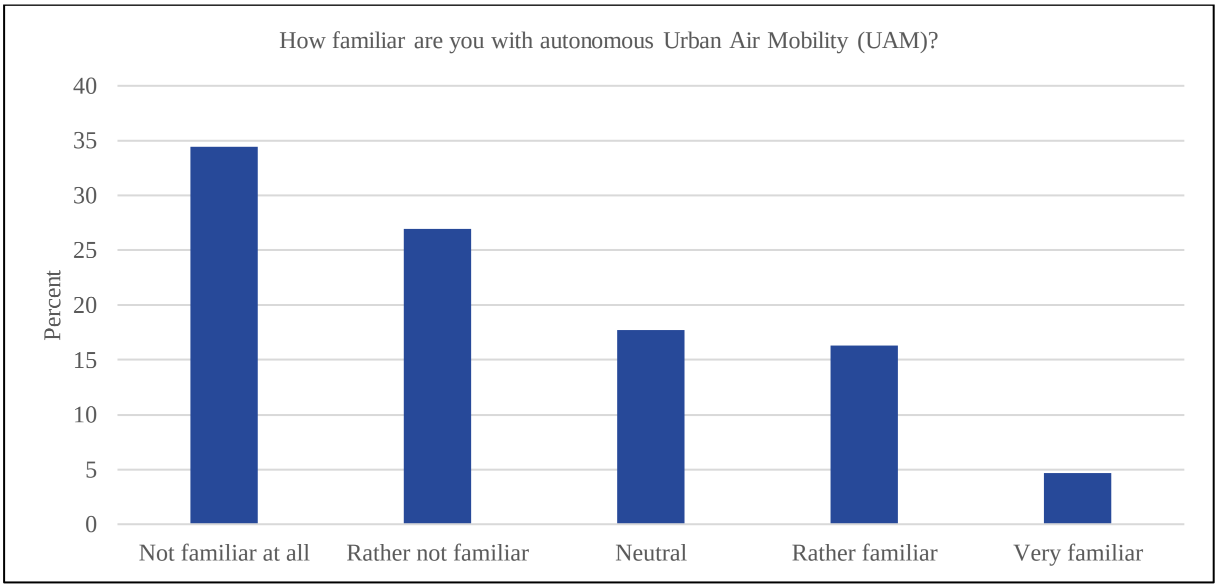


Chart 24: UAM-Q1

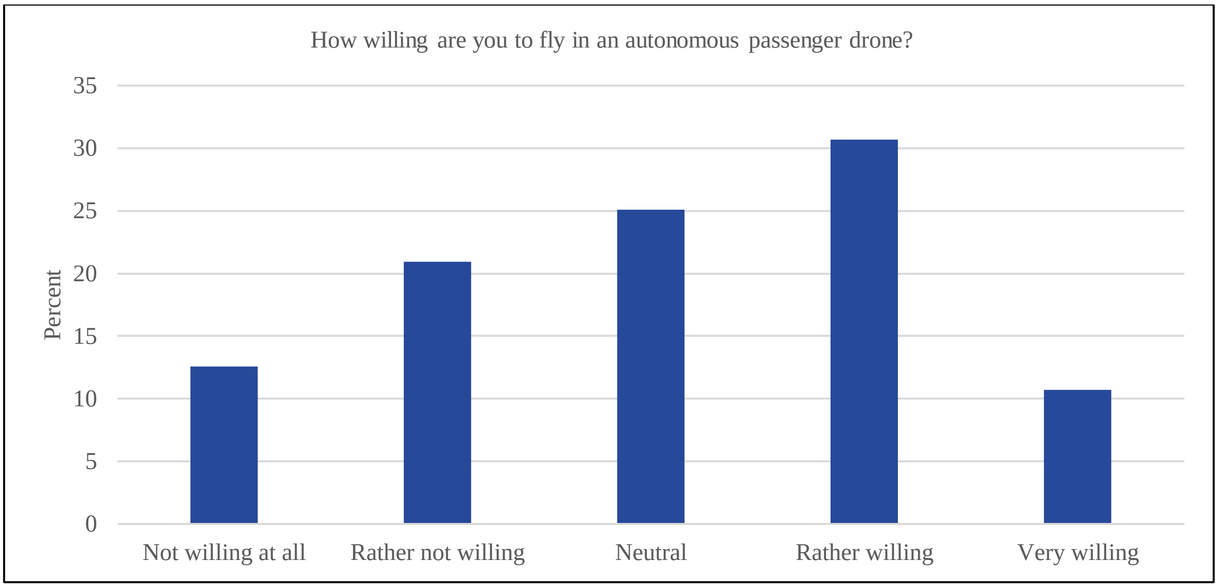


Chart 25: UAM-Q2

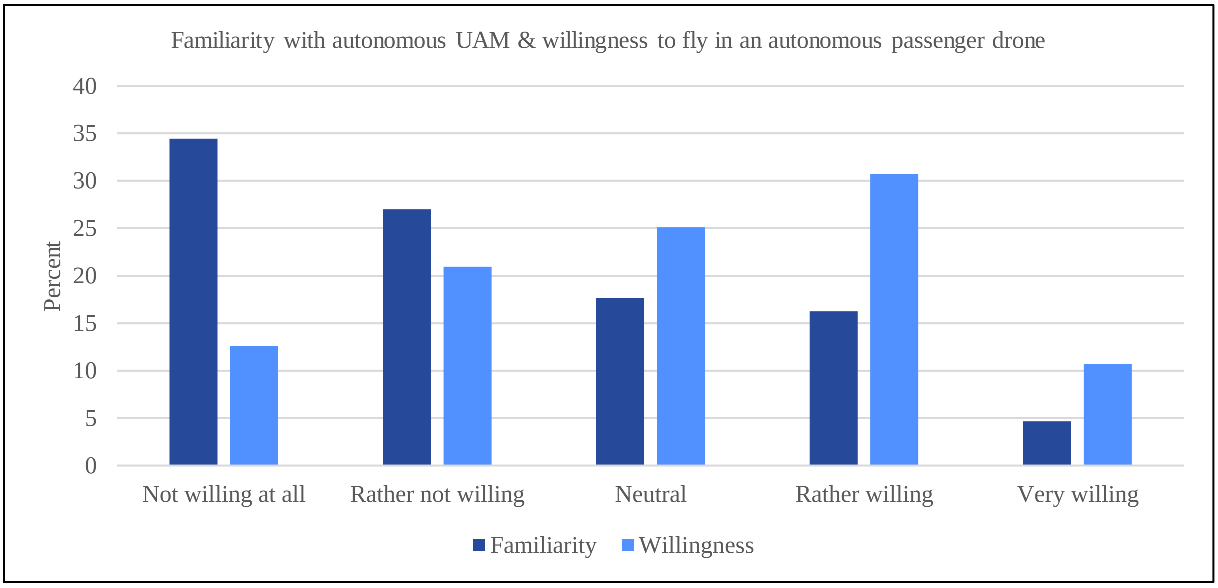


Chart 26: UAM Q1 & Q2

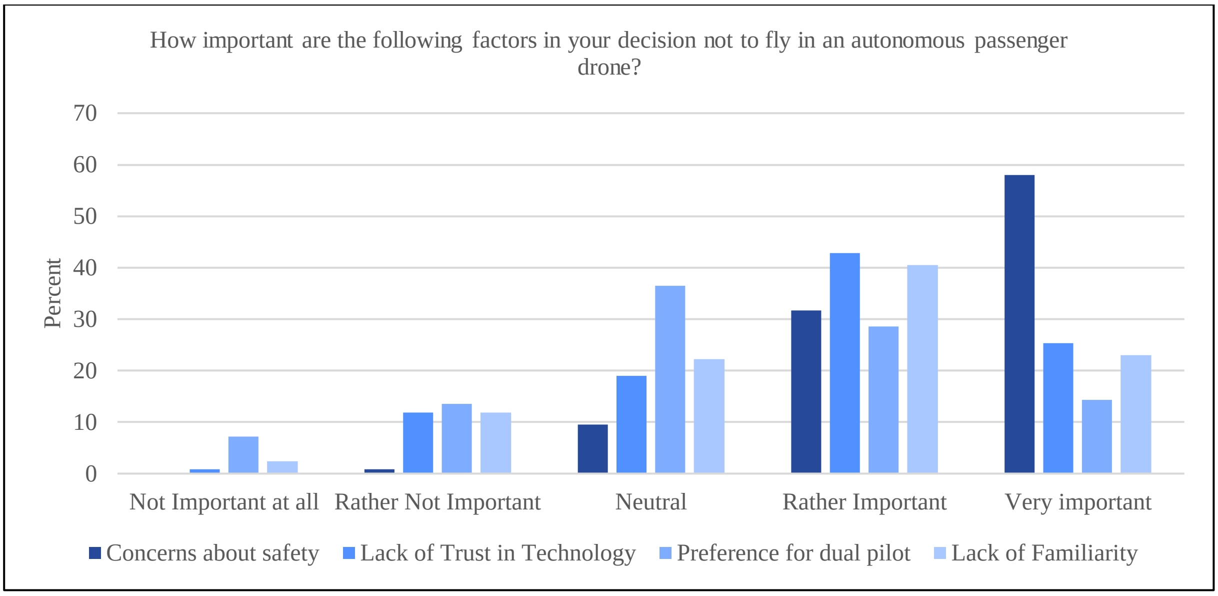


Chart 27: UAM-Q3

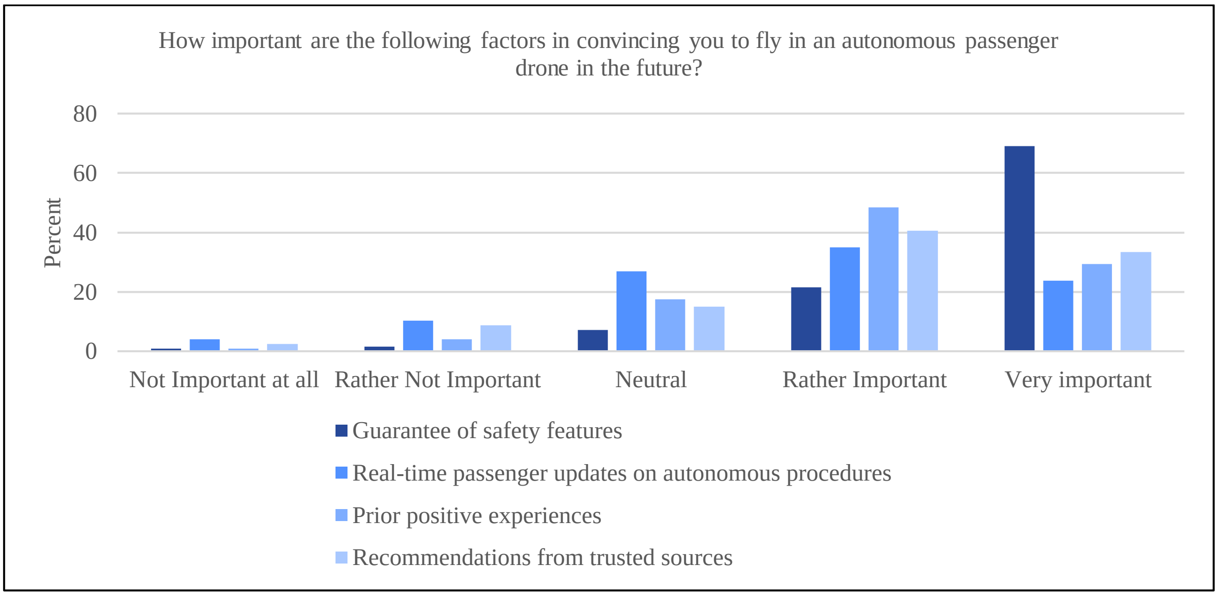


Chart 28: UAM-Q4 UW

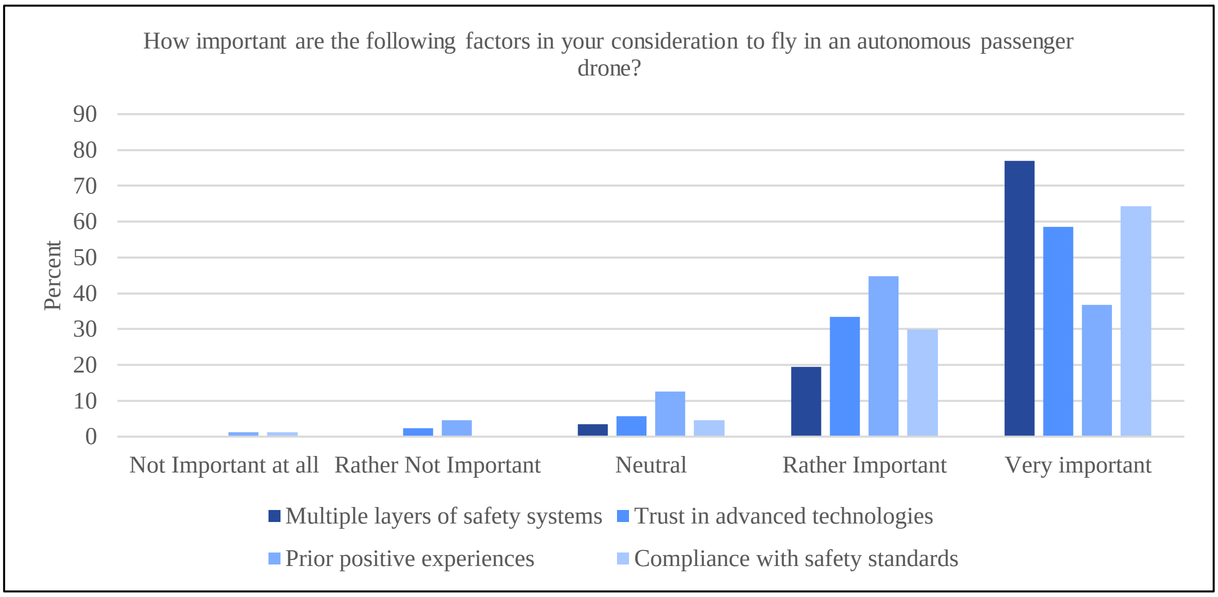


Chart 29: UAM-Q4 W

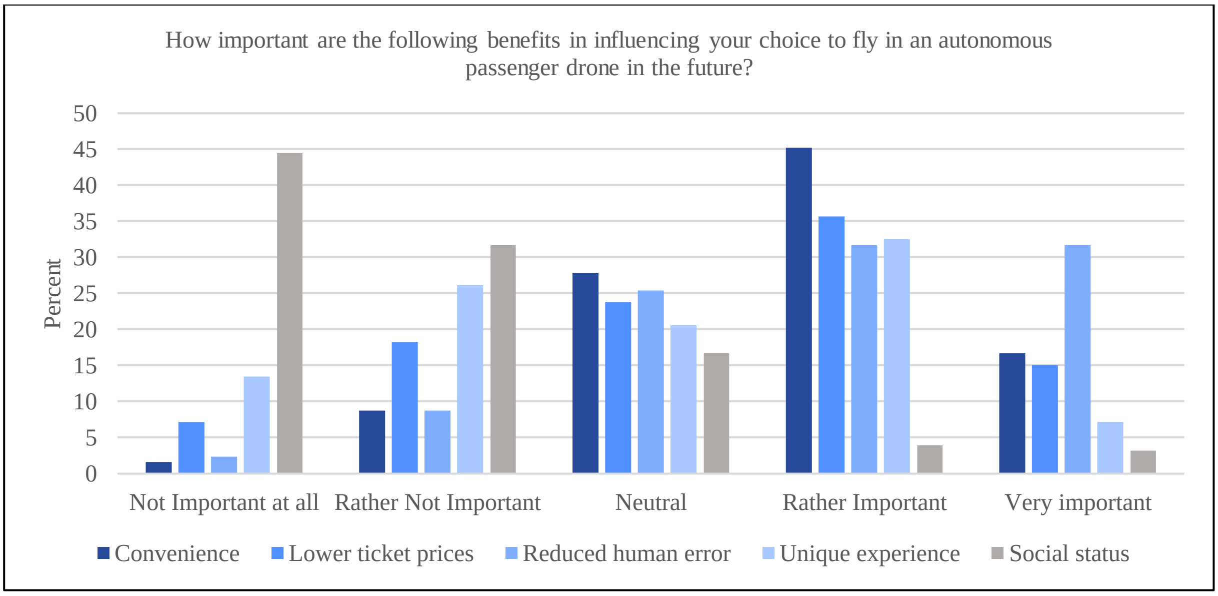


Chart 30: UAM-Q5 UW

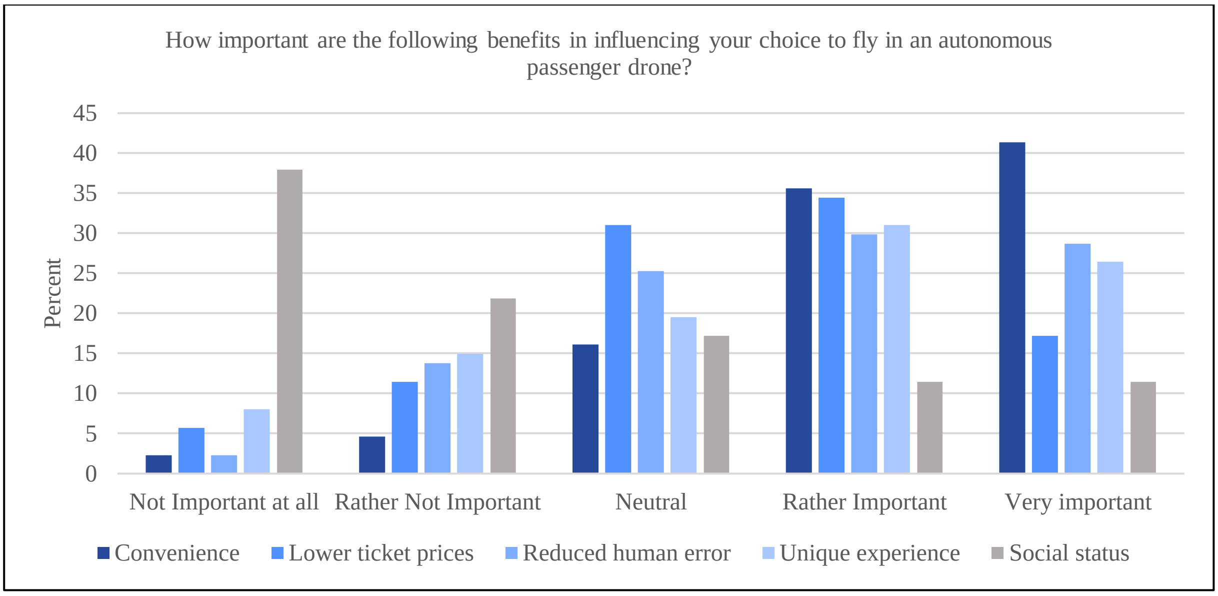


Chart 31: UAM-Q5 W

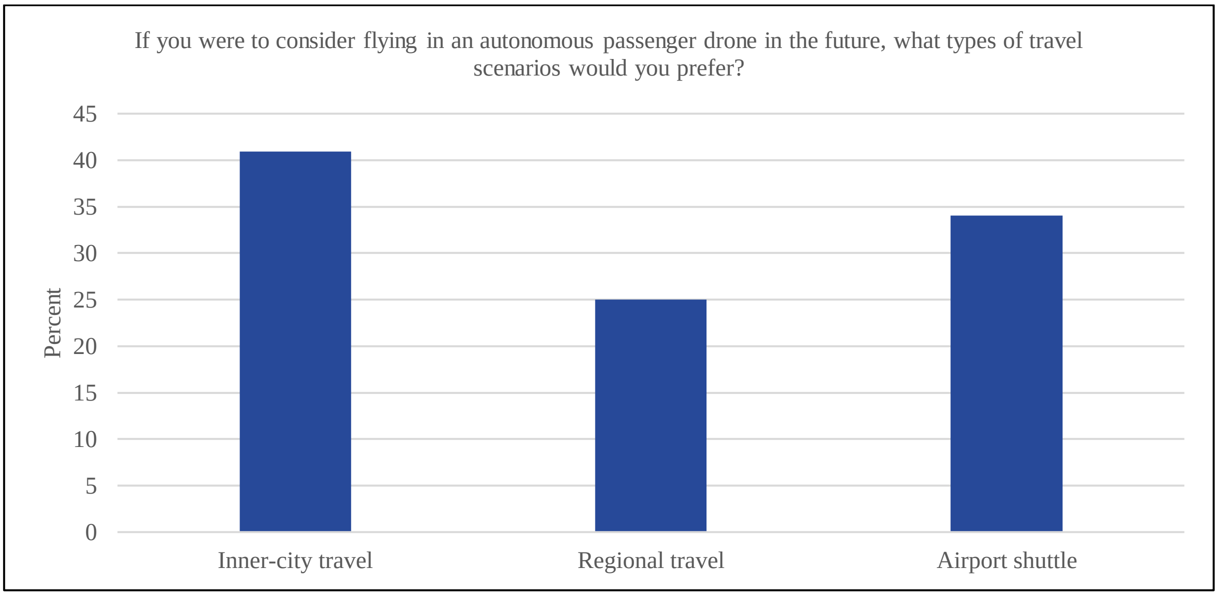


Chart 32: UAM-Q6 UW

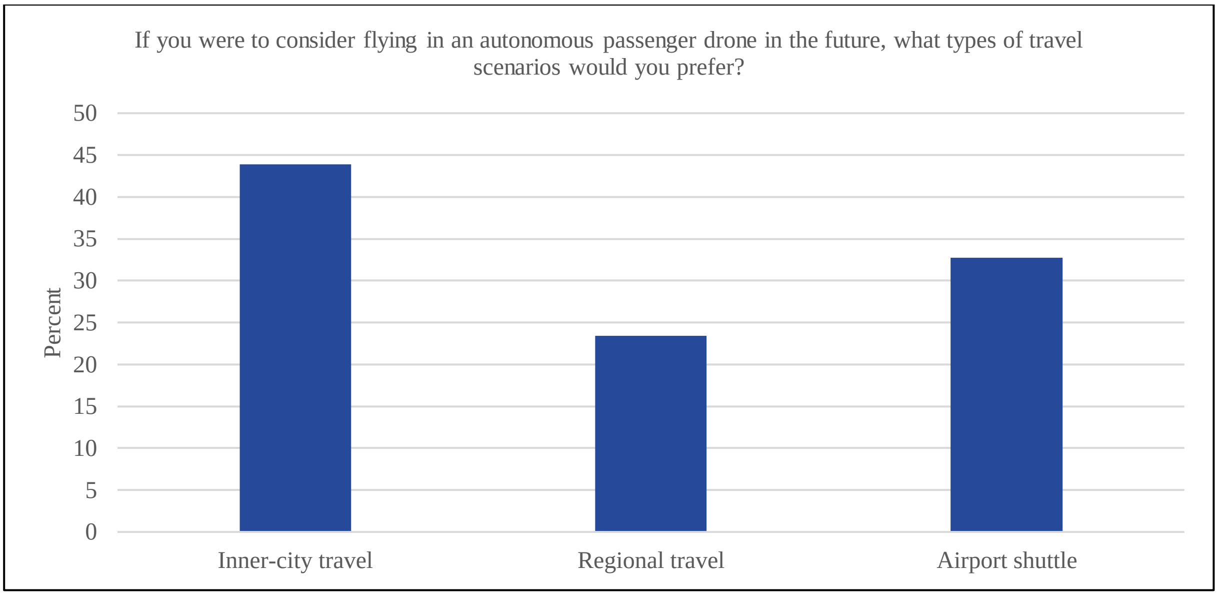


Chart 33: UAM-Q6 W

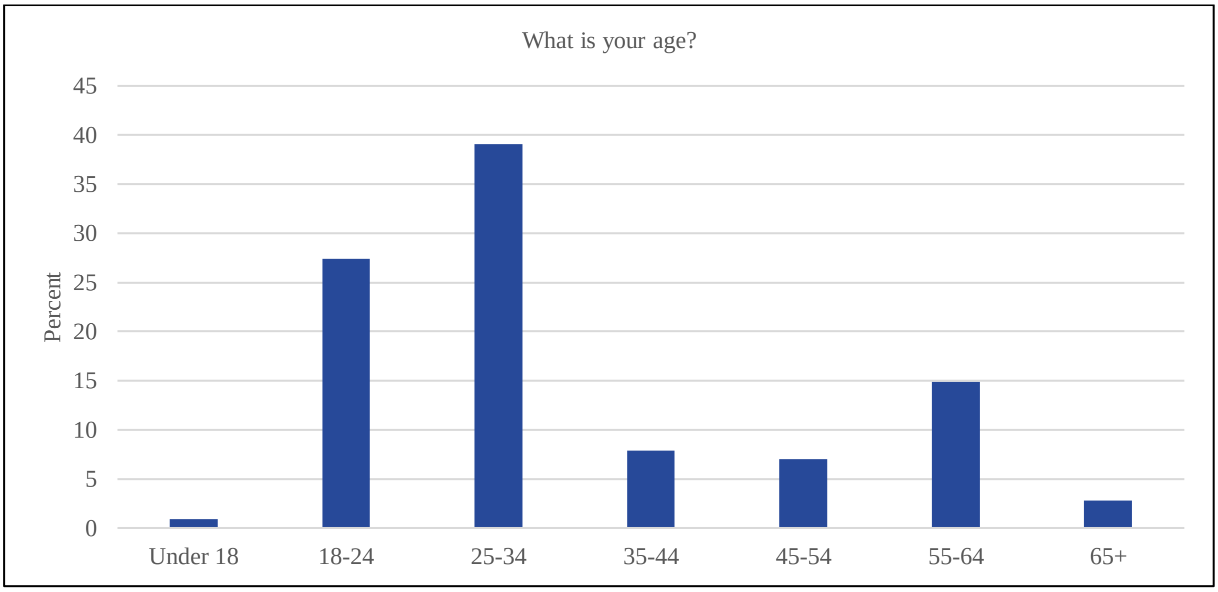


Chart 34: D-Q1

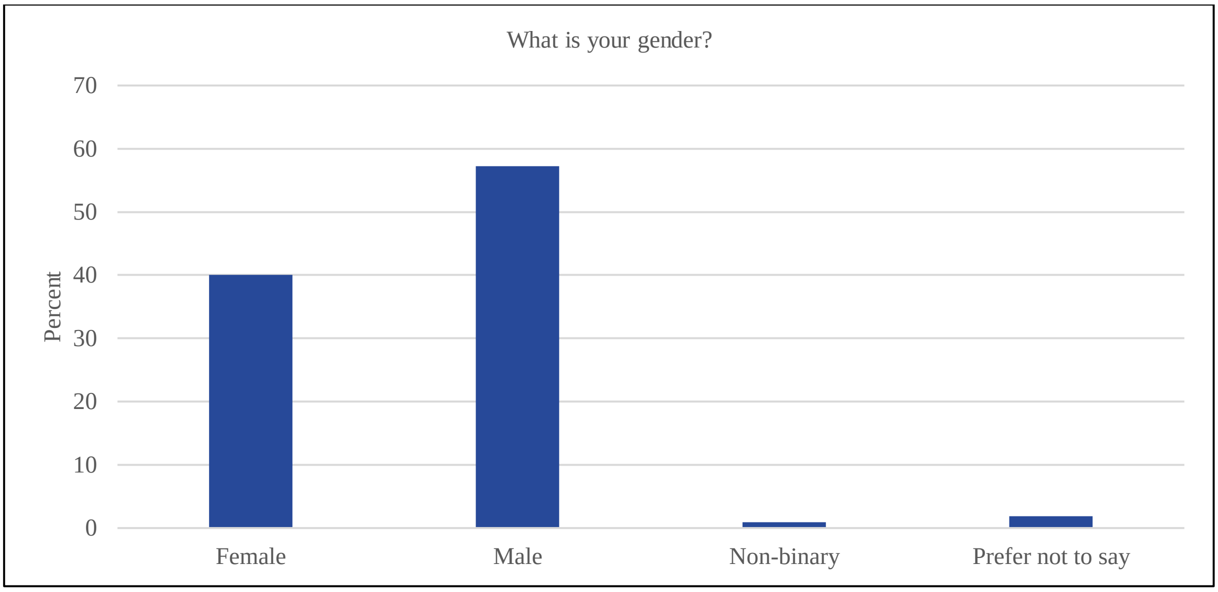


Chart 35:D-Q2

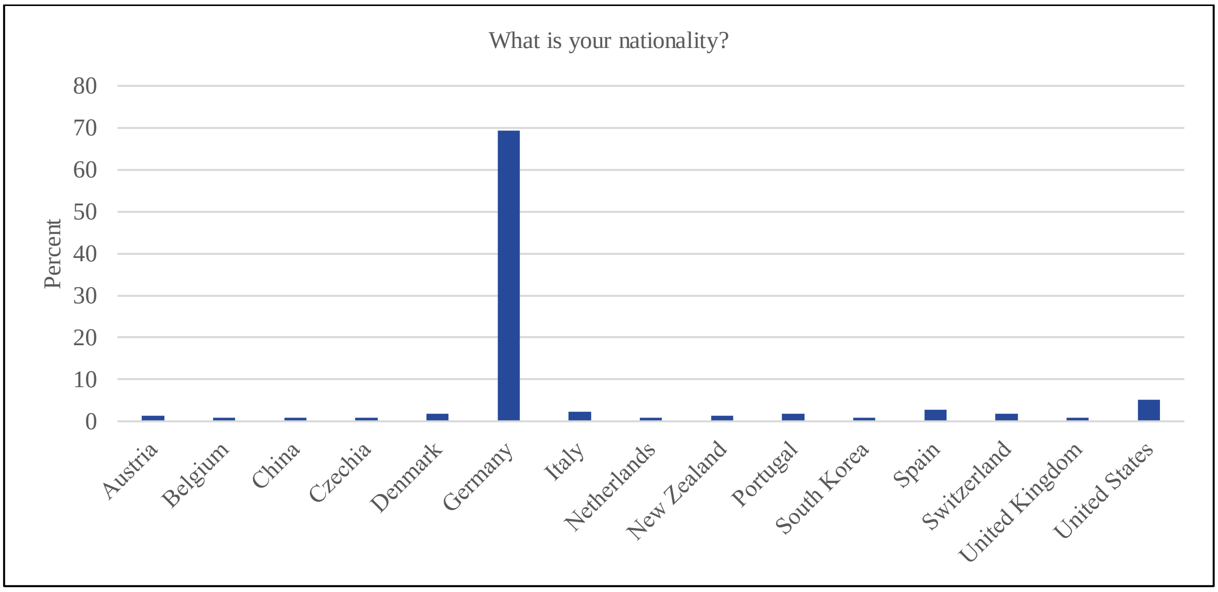


Chart 36: D-Q3 (nationalities that represent less than 1% of all nationalities have been left out for clarity purposes)

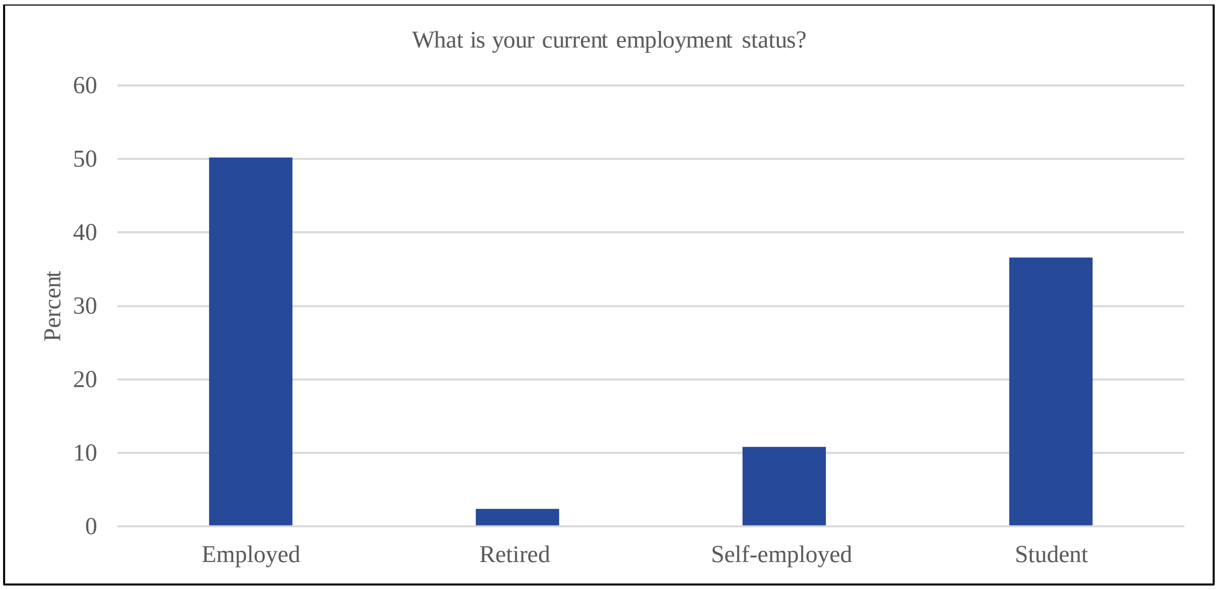
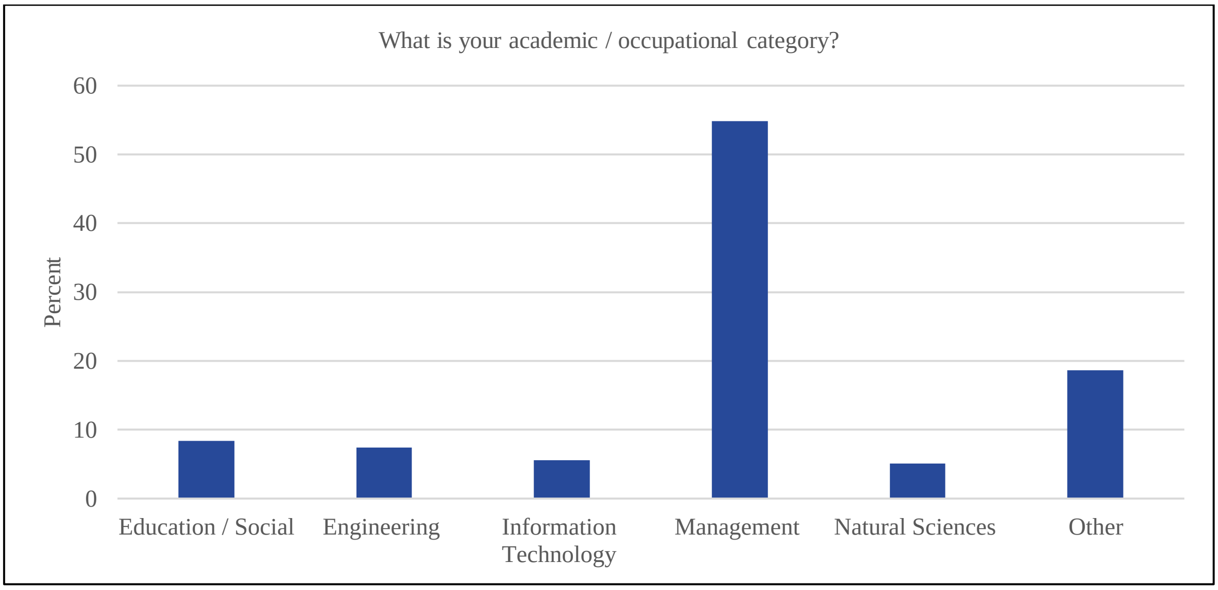


Chart 37: D-Q4



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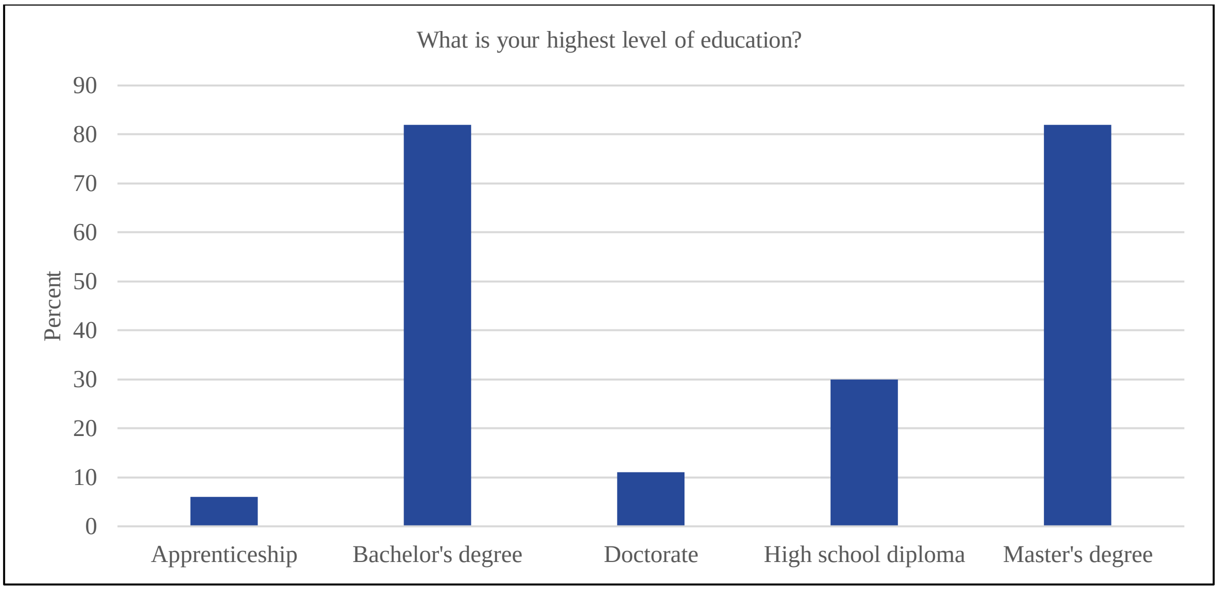

Chart 39: D-Q6

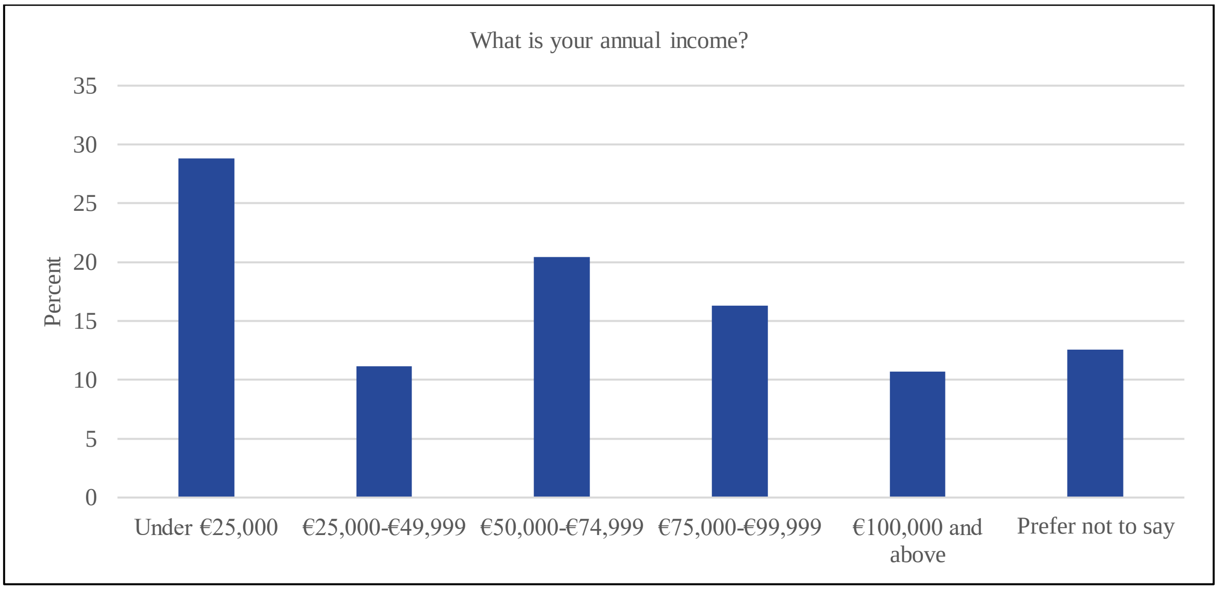

Chart 40: D-Q7

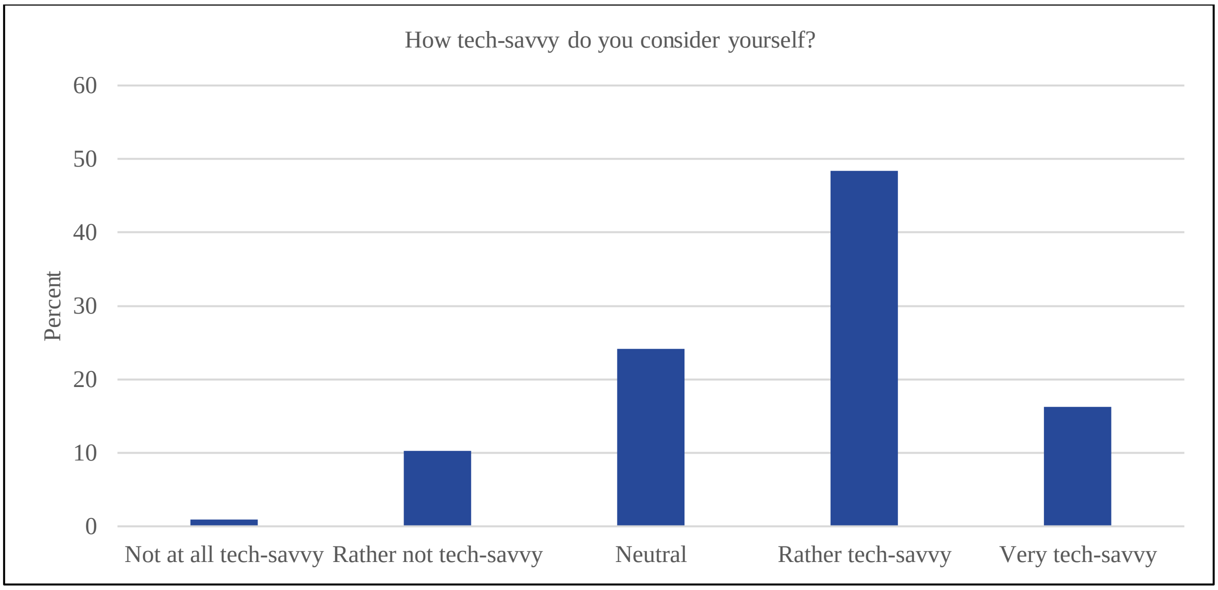

Chart 41: G-Q1

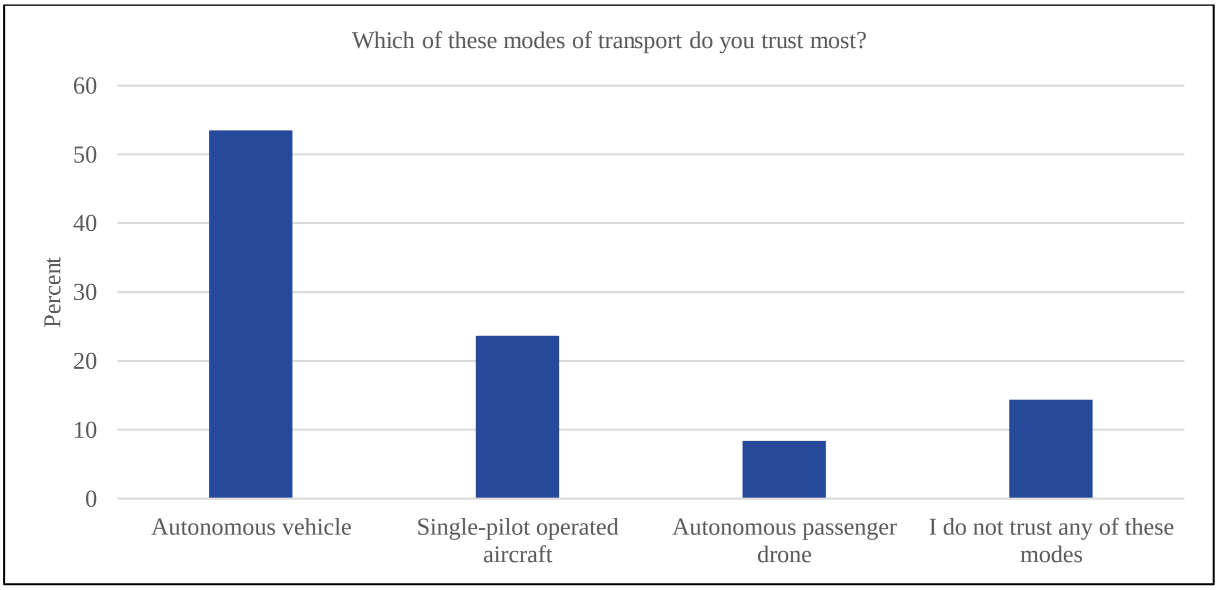

Chart 42: G-Q2