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Trusting Beliefs and Bases in the Adoption of Autonomous Last Mile Services (ALMS)

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Short Paper

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Abstract

Last mile connectivity is crucial in transporting people from a transportation hub to a final destination. Autonomous last-mile service (ALMS) is one of the latest solutions for this problem, offering on-demand transportation connecting to the primary transportation method and operated automatically. However, the implementation of ALMS poses several challenges. Trust is an essential factor in enabling users to overcome their concerns about risk and uncertainty. Although trust can be developed towards various entities, existing studies have only explored trust in autonomous vehicles, without addressing overall trust in the ALMS. Additionally, ALMS is a sophisticated social-technological service, consisting of multiple components that could lead to different trust bases. Our research aims to identify the factors influencing trust in ALMS and identify ways to promote trust and overcome potential obstacles to adoption.

Keywords: Autonomous last mile service, trust base, cost-benefit calculation, environmental impact

Introduction

Last mile connectivity refers to the transportation service that bridges the gap between a transportation hub and the final destination. It becomes necessary when the primary mode of transportation doesn't reach the final destination (Mohiuddin, 2021). Improved last mile connectivity can enhance individual mobility and quality of life, especially for those with limited access to public transportation (Webber et al., 2010). It enables older adults and individuals with disabilities to maintain independence by facilitating transportation to essential places like medical appointments and grocery stores. In urban areas, where congestion and parking constraints are common, last mile connectivity becomes even more crucial (De et al., 2019).

Due to the importance of last mile connectivity to individual mobility, governments have been taking steps to promote the development of last mile services. Paratransit service - a transportation option that provides individualized rides without fixed routes or timetables, primarily catering to the transportation needs of individuals with disabilities who cannot use regular fixed-route mass transit systems - was one of the most widely used last-mile solutions over the past decade in the U.S. (Cervero, 1997). This solution, however, has the disadvantage of being economically and environmentally inefficient in terms of scheduling, capacity, and routing (Phun and Yai, 2016; Goodwill and Carapella, 2008). Thus, in recent years, governments and companies have been actively working towards the development of autonomous last-mile service (ALMS). Initiatives like the UK's Intelligent Mobility (IM) and the EU's Urban Innovative Actions program are laying the foundation for ALMS implementation (Meyer, 2019). Companies such as Waymo and Uber are also investing in the development of autonomous vehicles for last-mile connectivity (de Miguel et al., 2020). ALMS offers several potential advantages, including 24/7 operation, optimized routes, reduced labor and fuel costs, and environmental benefits (Altaweel, 2018; Alexander-Kearns et al., 2016).

However, the adoption of ALMS encounters various challenges, such as implementation costs, technical obstacles, public distrust, and security concerns (Bucchiarone et al., 2021). While previous studies focused on autonomous last mile deliveries of goods, further exploration is needed to understand ALMS applications in passenger transport. Involving people in the process adds complexity as it requires engaging end-users and prompting behavioral change (Bucchiarone et al., 2021). Some users may prefer conventional delivery methods or existing transportation options over ALMS. Trust plays a vital role in facilitating behavioral change as individuals who trust the new service are more receptive to modifying their behavior. Trust fosters a sense of security and confidence, reducing resistance to change and promoting psychological safety. Moreover, trust plays a crucial role in helping users overcome their apprehensions regarding the risks and uncertainties associated with adopting new technology (Gefen et al., 2003; Li et al., 2008). In the case of ALMS, trust becomes even more critical due to the inherent risks involved, including safety, security, and privacy concerns, which diminish the predictability of outcomes and amplify uncertainty. Establishing trust is essential in such environments characterized by high levels of risks and uncertainties, as it becomes a key determinant for the development of successful long-term relationships (Bart et al., 2005; Adnan et al., 2018).

Although trust has been studied in relation to autonomous vehicles, the overall trust in ALMS has not been thoroughly explored. This is noteworthy because ALMS is a complex social-technological transportation service comprising multiple components that can elicit unique trust beliefs. For instance, ALMS incorporates autonomous vehicles for transportation, customer interfaces for managing and tracking rides, and infrastructure established by the government (Chee et al., 2020; Taeihagh and Lim, 2019). Trust in each of these specific elements may impact users' overall trust in the ALMS. Therefore, it is crucial to carefully examine the factors that influence trust at this early stage of ALMS development.

In this study, we aim to address the following research questions: What factors contribute to the development of trust in the delivery of ALMS? Our objective is to gain a comprehensive understanding of the external factors and internal beliefs that influence the adoption of ALMS, with the hope that our findings can assist governments and technology companies in effectively allocating their budgets by prioritizing the elements that have a greater impact on enhancing users' trust. Our study makes several contributions to existing literature. Firstly, we expand our understanding of new service adoption, which differs from new technology adoption due to the collaboration of various new technologies (such as autonomous vehicles and mobile apps) and the provision of novel physical services regulated by the government (such as shuttle services without fixed routes and with 24/7 availability). Secondly, we identify the antecedents of trust based on cognitive and calculative bases. The cognitive base is represented by the reputation of tech companies, while the calculative base is derived from cost and benefit calculations. Additionally, we identify seven dimensions of cost and benefit calculation, including availability, cybersecurity, privacy, reliability, service quality, usability, and environmental impact. Interestingly, our study reveals that the safety dimension does not significantly contribute to the cost-benefit calculation. Thus far, no research has endeavored to uncover the underlying mechanism of building trusting beliefs in ALMS applications in passenger transport.

Literature Review and Research Model

Trusting Belief

Trust is a multifaceted concept that has been explored by scholars in different fields, including social psychology, economics, and marketing. It serves as a universally recognized foundation for both economic and social interactions. Trust involves one party's willingness to place themselves in a vulnerable position in relation to the actions of another party, with the expectation that the other party will carry out a particular action, without requiring close monitoring or control structures (Mayer et al., 1995).

Trust research was initially developed within the context of interpersonal relationships, focusing on human trustees as the subjects of study. Scholars have identified various characteristics of trustees that contribute to trust formation. Mayer et al. (1995) focused on three interpersonal trust attributes - ability, benevolence, and integrity - when examining organizational trust dynamics. However, certain systems possess limited interactivity and exhibit fewer human-like traits, which may render it inappropriate for individuals to attribute human qualities like ability or benevolence to them. ALMS is designed as a non-human-like entity, operating autonomously and efficiently in performing specific transportation tasks. It lacks human

emotions and physical characteristics, making it unreasonable to apply human-like traits to it (McKnight, 2005). Consequently, it is more appropriate to use system-like technology trusting attributes to examine ALMS. Lankton et al. (2014) propose a conceptual framework for system-like technology trusting attributes, encompassing reliability (consistent and error-free operation), functionality (possessing necessary features and capabilities for task completion), and helpfulness (providing sufficient and responsive assistance).

Multiple studies have demonstrated the significant impact of trust on behavioral intention. Prior research has specifically highlighted trust as a key predictor of adoption intention when it comes to automated technology (Choi and Ji, 2015; Dirsehan and Can, 2020). However, while previous studies have primarily focused on investigating trust solely in the context of autonomous vehicles, it is essential to consider the broader spectrum of technologies that underpin ALMS. These technologies encompass autonomous vehicles, sensors, cameras, routing and navigation systems, communication systems, central command centers, maintenance and repair systems, mobile apps, and data management systems. Each of these technologies plays a crucial role in facilitating ALMS, and individuals' trust in the reliability, functionality, and helpfulness of these technologies can significantly influence their intention to utilize the service. Therefore, it is crucial to explore trust in the entire range of technologies that support ALMS to gain a comprehensive understanding of its impact on user adoption intention.

H1: Trust in technologies that support ALMS has a positive effect on intention to use ALMS.

Trusting Bases

In our study, we draw upon the existing literature in management and information systems research to identify the key determinants of trusting beliefs, known as trusting bases (Li et al., 2008). These trusting bases serve as the foundation for understanding the factors that influence individuals' beliefs in trust. By getting insights from various research areas, we aim to provide a comprehensive explanation of the determinants of trusting beliefs in the context of ALMS.

Previous trust research has proposed several primary categories of trust bases, each comprising sub-components that form the basis for the overall formation of trust. These bases are cognitive base, calculative base, institutional base, and knowledge base (Williamson, 1993; McKnight et al., 2002; Li et al., 2008). The knowledge base, which relates to one's past experiences, is not included in our model. It is because in the initial trust context, people always have no prior experience using ALMS. Thus, there is a lack of direct knowledge or experiential interaction with an unfamiliar trustee, making the knowledge base irrelevant to our study.

The institutional base means the established norms, rules, and regulations that guide behavior within a particular institutional context (Gefen et al., 2003). In the context of ALMS, which represents a new and innovative transportation service, there is no pre-existing institutional base that can be relied on to facilitate building trust. Therefore, individuals may face greater uncertainty and difficulty in building trust in ALMS, as there is no established institutional structure to provide reassurance or guidance.

Previous research on the cognitive basis of trust suggests that a trustor may use the reputation of an unfamiliar trustee to categorize them as trustworthy or untrustworthy, as reported by Li et al. (2008). In situations where direct experiential information is unavailable, a trustee's reputation can influence people's perceptions of the reliability, functionality, and helpfulness of technologies. Therefore, reputation is considered a significant subcomponent of the cognitive basis of trust. Technology companies are often seen as experts in their field, with a reputation for innovation and cutting-edge technology. This can transfer over to autonomous shuttles and the supporting technologies, which are relatively new technologies. Users may trust the technologies more if they are developed by a reputable technology company. When users have a clear understanding of how the technology works and the steps taken to ensure its safety and reliability, they are more likely to trust the service. Accordingly, the following hypothesis is proposed:

H2: Reputation of technology companies has a positive effect on trust in technologies that support ALMS.

Past studies examining the calculative basis of trust have posited that individuals are likely to act in accordance with economic principles when engaging in trust-related behaviors (Williamson, 1993). When faced with the decision to trust an unfamiliar trustee or a familiar trustee in a new situation, the trustor typically assumes that the trustee is rational and calculative and will prioritize their self-interest. Therefore, when someone is in a position where they have to decide whether to trust the trustee or not, they are more

likely to trust the trustee if they believe that the trustee has nothing to gain by being untrustworthy or if the potential costs of being untrustworthy are too high.

Previous research has highlighted the relevance of calculative trust in the development of initial trust (Li et al., 2008). When individuals encounter a new technology and are considering whether to trust it, they often experience a sense of vulnerability regarding potential misuses or abuses of the technology, such as unauthorized use of personal information. Consequently, users' assessment of the potential costs and benefits associated with such misuse or abuse plays a significant role in shaping their initial trust in the technology. If users perceive that the technology and its stakeholders, such as technology companies and related agents, have no incentive to act in an untrustworthy manner or that the costs of doing so outweigh the benefits, they are more likely to form positive, initial trust in the technology. As a result, we propose the following hypothesis:

H3: Cost and benefit calculation has a positive effect on trust in the technologies that support ALMS.

To get a better understanding of the calculation of costs and benefits, we explore the specific costs and benefits associated with trust in the technologies that support ALMS. Previous research has identified several benefits and costs related to autonomous vehicles in last mile delivery. For instance, He and Li (2021) demonstrated that autonomous vehicles have the potential to optimize last-mile delivery, leading to improved efficiency and reduced congestion on urban roads. It can also contribute to lower emissions, thus promoting environmental sustainability. Similarly, according to Rosenberger (2023), autonomous last mile service has the capability to provide personalized experiences to individuals. Through the use of mobile apps and other user interfaces, individuals can have greater control over their transportation preferences, such as selecting specific routes or customizing the service to align with their special needs.

Furthermore, we conduct a comprehensive review of trust research in the areas of emerging technology, transportation, and paratransit to identify the factors that may influence trust. Hoffman et al. (2006) proposed a general trust model that emphasizes the impact of various factors on trust, including availability, security, usability, privacy, and reliability of the technology. Similarly, Allen et al. (2019) suggested that users' transportation requirements can be classified into three distinct levels, these levels encompass functional attributes such as frequency, accessibility, reliability, and speed; security attributes such as safety; and hedonic attributes such as ride comfort and customer service (Chee et al., 2020). Additionally, Joewono and Kubota (2007) identified a range of attributes related to service quality in the context of paratransit, including availability, accessibility, reliability, information availability, customer service, comfort, safety and security, fare, and environmental impact.

After synthesizing the relevant articles on the benefits and costs of ALMS to individuals, we have mapped these factors onto the trust antecedents typologies mentioned earlier. As a result, we identify the following factors that contribute to the calculation of costs and benefits:

1. Availability: Users need to know that the ALMS will be available whenever they need it. It can offer users a more flexible, 24/7 and on-demand transit option. Traditional public transportation systems operate on fixed routes and schedules, limiting their availability and making it challenging to provide transit services to all areas of a city or town. However, ALMS can be deployed more dynamically and can adapt to the specific transit needs of users in different areas anytime.
2. Cybersecurity: Users need to feel confident that their personal and financial information is secure while using this ALMS service. As with any technology connected to the internet, ALMS could also be vulnerable to hacking, which could lead to safety risks and financial losses. Therefore, the service must have robust security features in place to protect user data from unauthorized access or use.
3. Privacy: ALMS generates a significant amount of data about their surroundings and their passengers, which could raise privacy concerns. Users need to know that their personal data is being handled carefully and not being misused. The service should be transparent about how they collect and use their data and provide them with the option to opt-out or delete their data.
4. Safety: Safety is a critical factor as users want to trust the technology with their lives. ALMS must be designed and operated in a way that ensures the safety of users and others on the road. Autonomous vehicles are equipped with advanced technologies such as LiDAR, GPS, and computer vision. They could help them navigate through traffic and avoid obstacles (Keysight, 2022). This can help reduce the risk of accidents and improve overall safety for drivers, passengers, and

pedestrians. However, some individuals may not be fully aware of the capabilities of autonomous vehicles and prefer to have control over their own vehicle. They may have concerns about the vehicle's ability to handle unexpected situations or potential malfunctions that could arise.

5. Reliability: Users want to rely on technology that is consistent and predictable. ALMS is necessary to ensure that passengers are transported to their desired destination accurately and punctually without any errors. Therefore, the technology must be tested thoroughly to ensure that it works correctly in different situations.
6. Service quality: To cater to users' requirements effectively, the service should be designed to offer high quality services, including seamless boarding and disembarking, a comfortable and smooth ride, and satisfactory trip completion.
7. Usability: The communication technologies must be easy to use, intuitive, and free of glitches. Users want to be able to use the app efficiently without any issues. Passengers should have the flexibility to book their ride via a mobile app or a web interface and specify their pickup and drop-off locations. During the ride, it offers real-time updates on the journey, including the estimated time of arrival, the route being taken, and any delays or detours. Additionally, it should process payments automatically. Passengers can also view their trip history and receipts via the platform.
8. Environmental impact: Autonomous vehicles can be designed to run on cleaner energy sources, reducing the amount of greenhouse gases emitted by the transportation sector.

The conceptual research model is shown in Figure 1.

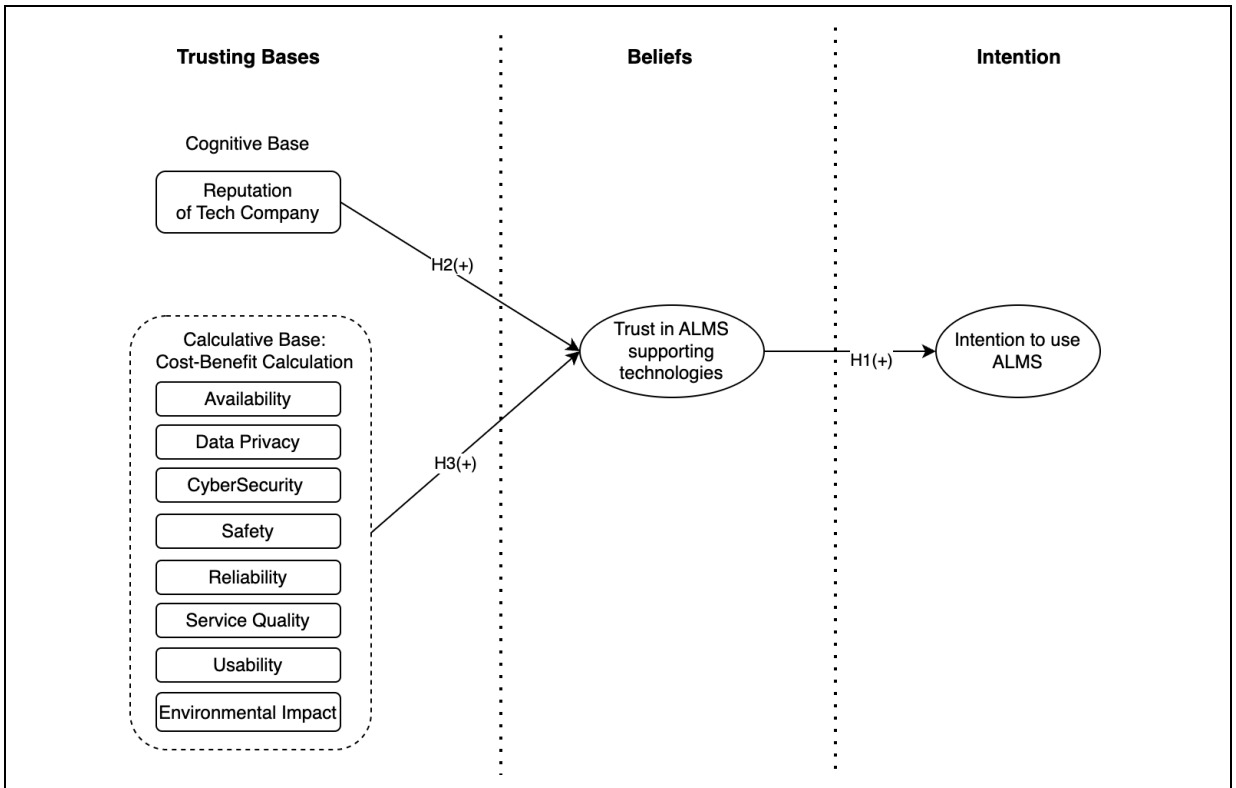

Figure 1. The Conceptual Research Model

Research Method

Measurements

We conducted a survey among U.S. urban area residents. A preliminary set of instrument items was developed for each construct based on scales from the extant literature. At least three reflective items were used to measure each construct. Each item was measured on a five-point Likert scale. To measure intention to use ALMS, we drew upon existing measures for technology acceptance model (Davis, 1989; Hu et al., 1999). We adapted Belanche et al.'s (2014) trust in public e-services and Lankton et al.'s (2014) trust in technology to measure the trusting beliefs (i.e., trust in ALMS, trust in public transportation, trust in technologies that support ALMS). Measures for public transportation satisfaction was adapted from previous studies about public transit and paratransit satisfaction (Lai and Chen, 2011; Rahman et al., 2016). Measures for reputation was adapted from Li et al.'s (2008) reputation for national identify systems. For the eight dimensions of cost-benefit calculation, the scales of availability, cybersecurity, privacy, and usability were adapted from Hoffman et al.'s (2006) study on general trust model; the scales of safety came from Barling et al.'s (2002) research about occupational safety and literature about cybersecurity; technology reliability was measured based on Lankton et al.'s (2014) trust in technology model; and service quality was adaped from Joewono and Kubota's (2007) paratransit service quality. New scales were also added to these dimensions based on the definition and benefits of AMLS.

The approach we adopted for developing the instrument measurements was proposed by Straub (1989). Initially, a preliminary set of items was evaluated by three business scholars in a pre-test phase. After incorporating their feedback and making necessary revisions to the questions, a pilot test was carried out involving fourteen university students to further refine the questions. All suggestions were carefully considered, and necessary modifications were made, such as rephrasing certain items to enhance simplicity and clarity.

Data Collection

The questionnaire was distributed to respondents electronically through Qualtrics online survey platform. We utilized Amazon Mechanical Turk (AMT), a crowdsourcing website for individuals and businesses to outsource their tasks, to survey urban residents in the U.S. The survey was sent to a random sample who were at least 18 years old and with equally distributed gender groups. Each respondent should live in the U.S. urban areas and have the experience of using public transportation services. A total of 380 completed responses were collected. Next, we eliminated responses that had a response time less than half of the average or failed the validation test, which involves identifying divergent answers to identical questions located in different sections of the survey. Finally, we got 236 (62.1%) qualified responses from AMT.

Results and Findings

Based on the preliminary descriptive results, we discovered that there is a significant proportion (25.0%) of urban residents are hesitant to embrace the ALMS once it becomes accessible in the future, and 19.5% of them exhibit complete distrust towards it. As a result, it is necessary to conduct research to investigate methods for enhancing their trust and willingness to adopt the ALMS.

We analyzed the data using covariance-based structural equation modeling (SEM) as all the latent variables had reflective measurements rather than formative measurements, since we were trying to test a theory. SPSS AMOS was chosen for this analysis. After checking the convergent validity and discriminant validity of the measurement scales, we proceeded to examine our structural model.

Our study utilized second-order CFA as a means of verifying that the cost-benefit calculation was a second order construct incorporating first-order dimensions. The results indicated that the cost-benefit calculation construct demonstrated significant loadings in seven of the eight first-order factors (with safety being the only non-significant factor). The factor loadings and corresponding p-values are presented below: (1) Availability ($b = 0.847$, $p < 0.001$); (2) Data privacy ($b = 0.89$, $p < 0.001$); (3) Cybersecurity ($b = 0.745$, $p < 0.001$); (4) Safety ($b = 0.044$, $p = 0.595$); (5) Reliability ($b = 0.796$, $p < 0.001$); (6) Service quality ($b = 0.871$, $p < 0.001$); (7) Usability ($b = 0.519$, $p < 0.001$); (8) Environmental impact ($b = 0.183$, $p = 0.043$).

We found that the safety dimension did not significantly contribute to the cost-benefit calculation. A basic descriptive analysis of survey results showed that despite more than half of the respondents expressing some safety concerns, only 20% reported having low trust in supporting technologies. This suggests that while most people acknowledge the potential safety risks associated with autonomous vehicles, they still believe that the benefits outweigh the risks. A reason may be that people perceive autonomous vehicles and related technologies as being safer than human-driven vehicles. For example, autonomous vehicles are less likely to be involved in accidents caused by human error, such as distracted driving or driving under the influence. People may believe that the rapid advancement of technology and the implementation of sensors, machine learning, and artificial intelligence will ultimately lead to a reduction in accidents and errors compared to human-driven vehicles. Additionally, people may believe that the safety issues associated with supporting technologies are manageable. They may believe that any issues can be mitigated through measures such as driver education, enhanced vehicle maintenance, and improved infrastructure. These findings add to the existing literature on trust, which has rarely investigated the underlying mechanisms that shape trusting beliefs in ALMS. Significantly, our study challenges conventional wisdom by revealing that safety is not a primary determinant in people's assessment of the potential costs and benefits associated with supporting technologies.

Our results also indicated that all path coefficients for hypotheses 1 to 3 are significant, providing support for the following relationships: (1) Trust in ALMS supporting technologies and intention to use ALMS (H1) (with a standardized coefficient of $b = 0.79$, and a significance level of $p < 0.001$); (2) Reputation of technology company and trust in supporting technologies (H2) ($b = 0.24$, $p = 0.008$); (3) Cost and benefit calculation and trust in supporting technologies (H3) ($b = 0.703$, $p < 0.001$).

Conclusion

Our research offers a comprehensive model that elucidates the mechanisms involved in establishing trust among residents, which can enhance the likelihood of successful adoption of Autonomous Last Mile Services (ALMS). With the increasing focus on sustainable transportation options, ALMS has gained prominence as an efficient and eco-friendly mode of transportation in urban areas. However, the adoption of ALMS could be postponed due to several challenges, especially the lack of trust in the service among potential users. Therefore, it is imperative to understand how to build trust among residents to increase the adoption rate of ALMS.

After analyzing the data, we summarize that the adoption of ALMS relies heavily on technology companies' ability to address key concerns of potential customers and build initial trust. Although safety is always a crucial factor to be considered by customers and can significantly impact a company's reputation, there are other key factors that have a greater impact on users' decision to adopt this service. One category of the primary concerns is about privacy and cybersecurity. Users need to be reassured that their personal information and the data generated through the service will be protected. Technology companies need to prevent any unauthorized access to personal data and provide users with the options to manage their data properly. Other important factors are reliability and availability. Users need to be able to trust that the technology will consistently provide reliable rides. This includes making sure that the vehicles are properly maintained and technology is functioning as expected. Companies must also provide rides that are always available to customers upon request. Additionally, the quality of service is important to users, who expect a high level of customer service, such as clean and comfortable vehicles, a smooth getting-on and off process, and prompt responses to any issues that may arise. Finally, technology companies must ensure that their applications or websites are user-friendly. This includes providing clear and easy-to-understand instructions for using the service, features that make it easy to book a ride, track the vehicle's progress, and provide feedback. By addressing these concerns, technology companies can increase the likelihood of adoption of ALMS.

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