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DOI
10.1016/j.trip.2024.101228

Publication date
2024

Document Version
Final published version

Published in
Transportation Research Interdisciplinary Perspectives

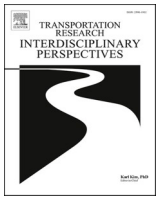
Citation (APA)
Kim, S., Anjani, S., & van Lierop, D. (2024). How will women use automated vehicles? Exploring the role of automated vehicles from women's perspective. *Transportation Research Interdisciplinary Perspectives*, *27*, Article 101228. https://doi.org/10.1016/j.trip.2024.101228

Transportation Research Interdisciplinary Perspectives 27 (2024) 101228

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

journal homepage: www.sciencedirect.com/journal/transportation-research-interdisciplinary-perspectives



How will women use automated vehicles? Exploring the role of automated vehicles from women's perspective

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ARTICLE INFO

Keywords:
Automated vehicles
Women
Mobility
Acceptance
Safety
Inclusive mobility

ABSTRACT

The emergence of automated vehicles promises a revolution in urban mobility. To benefit from a new mobility system, women who have specific mobility considerations necessitate inclusion in designing automated vehicles. This study explores women's perspectives and the potential impact of automated vehicles through focus group discussions and in-depth interviews. Results demonstrate concerns among women about safety in current mobility systems, vulnerabilities regarding personal safety, and stereotypes about female drivers. Additionally, mothers face additional challenges managing items for children and their demands during travel, and senior women consider safety issues and declining capabilities when contemplating driving cessation. Current experience with mobility is reflected in concerns and visions regarding automated vehicles. The absence of a driver is expressed as improved safety in driverless taxis, while it is perceived as a safety concern in automated public transportation. Mothers with children anticipate convenience in travel, whereas senior women expect enhanced mobility and social participation. These findings underscore the importance of safety in women's mobility experiences and provide insights into addressing safety and interaction issues in the design of automated vehicles. Researchers, transportation authorities, and vehicle manufacturers can leverage these results to understand women's needs better and consider them in future designs and policy developments for automated vehicles. Prioritising women's perspectives in automated vehicle research is essential to realising the innovative potential of this technology and fostering a more inclusive and accessible future in urban mobility.

1. Introduction

The emergence of automated vehicles (AVs) promises to enhance road safety, reduce congestion, and curb urban pollution in urban mobility (Correia & van Arem, 2016; Luettel et al., 2012). While the discourse surrounding automated vehicles and their impact on safety and comfort gain momentum, questions persist regarding their broader societal effects, especially regarding social equity (Harper et al., 2016; Wu et al., 2021). The effects of automated vehicles are not homogenous across socioeconomic and demographic strata. Despite initial attempts to address this divergence (Cohen et al., 2017; Milakis et al., 2017), the literature remains deficient in discussing these disparities (Douma et al., 2017), leaving policymakers and society with difficulty in preparing to mitigate potential inequities. Consequently, some individuals who stand to benefit from automated vehicles may face challenges due to their circumstances or lack of consideration in the design and implementation of AV-related policies.

Women account for 49.7 % of the world population (Worldbank, 2022), but they stand as a demographic where the intersection of social equity, transport disadvantage, and the risk of social exclusion is well-established (Hortelano et al., 2021). While in the realm of automated vehicles, certain needs of women often need to be addressed (Murphy et al., 2023; Pflugfelder, 2018), research incorporating these specific needs of women is lacking. Safety is a critical consideration for women's mobility (Stark & Meschik, 2018), and women's mobility patterns differ significantly from men, with more non-work-related trips (Perez, 2019), off-peak hour travel, and a greater reliance on flexible transport modes. Such differences and nuances have yet to be understood and much less addressed by policymakers (Loukaitou-Sideris, 2016).

The advent of automated vehicles is expected to carry substantial implications for women. There exist several speculative assumptions regarding the impact of automated vehicles on women's mobility. Automated vehicles offer frequent and additional services, allowing women exposed to late-night safety threats to avoid dangerous

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https://doi.org/10.1016/j.trip.2024.101228
Received 5 May 2024; Received in revised form 29 August 2024; Accepted 14 September 2024
Available online 26 September 2024

situations (Singh, 2020). In addition, automated vehicles are expected to streamline women's complex mobility patterns, enabling smoother execution of domestic chores and family-related travels and offering enhanced personal safety (Alonso-Almeida, 2019; Ng & Acker, 2018). Automated vehicles, especially shared mobility options, could offer women more attractive alternatives to private transport, presenting economic and environmental benefits (De Luca & Di Pace, 2015; Denton, 2002; Gossen & Purvis, 2004; Polk, 2003). However, at the same time, specific challenges need to be identified and solved for automated vehicles to be fully realised in enhancing women's mobility. For example, compared with men, women usually show more worries over crime and security issues when travelling (Goddard et al., 2006). Research is needed to understand women's perspectives on current mobility and automated vehicles to foster the acceptance of automated vehicles and their societal impact on women's mobility.

In this study, we examine women's current mobility patterns and explore how automated vehicles could meet their needs, addressing both visions and concerns associated with these vehicles. Our aim is not only to adopt a gender perspective on future modes of transportation but also to gain insights into current behaviours and how future modes could address or enhance travel, particularly focusing on issues that are gender-related disparities.

1.1. Women's perspective of automated vehicles

The gender demographic approach of automated vehicle research mainly focused on the perception of technology according to gender, such as intention to use and willingness to buy. Previous studies have shown that men generally exhibit higher acceptance levels toward automated vehicles compared to women. They tend to be more familiar with automated driving functions (Kyriakidis et al., 2015), show a greater willingness to pay for automation (Hohenberger et al., 2016), appear less concerned about safety (Liljamo et al., 2018), exhibit less fear about driving in automated vehicles (König and Neumayr, 2017), and demonstrate greater trust in AV technology (Choi & Ji, 2015). However, regarding the attitude toward public transportation, Nordhoff et al. (2018) and Madigan et al. (2017) found no gender effects on individuals' behavioural intentions to use the automated shuttle.

Previous studies have attempted to explore the impact of AV on women's mobility. Grosso et al. (2022) reported that automated vehicles hold the potential to meet women's mobility improvements and needs yet concurrently raise concerns regarding safety and privacy. Wu et al. (2021) suggested that caregiving roles, low income, and discrimination are representative disadvantages in women's mobility, and Automated vehicles could enhance women's trip chaining and driving experience and improve safety. Additionally, Schuß et al. (2022) investigated women's security requirements, suggesting interaction design insight to enhance perceived security in shared automated vehicles. However, despite these efforts, there remains a research gap in exploring AV design implications based on women's mobility needs and perspectives on Automated vehicles, which is crucial for supporting women's mobility.

1.2. Automated vehicles

Automated vehicles are expected to potentially limit crashes and make roads safer for all who travel on them. However, the impact may vary depending on vehicle design, service, and interaction with the deployment environment. For example, the existing literature can identify various automated vehicle scenarios involving capacity, cost, whether the vehicle is for personal or shared use, on-demand, reservation use, and owned by the public or private. This study focuses on evaluating women's opinions on the following four options: (1) automated public transportation with fixed schedules, routes, and timetables, (2) on-demand public shared automated vehicles, and (3) fleet-based shared automated vehicles, and (4) privately owned automated vehicles, with reference to (Faber & van Lierop, 2020). The vehicles in the scenario were introduced to participants in the study as all involved full driving automation (SAEInternational, 2021) to handle all driving tasks.

1.2.1. Automated public transportation with fixed schedules, routes, and timetables

Automated public transportation is the automation of conventional forms of public transportation that operate with fixed schedules and routes. Passengers can board and alight taking place at specified transportation stops and stations (Alessandrini et al., 2015). The automation of conventional public transportation significantly enhances punctuality and facilitates increased service frequency during and beyond regular operating hours, optimising infrastructure utilisation (Begg, 2014). Anticipated enhancements in service frequency primarily arise from reduced operational costs, given the elimination of the need for human operators to manage vehicles (Cats & Haverkamp, 2018). This service is provided within a specific region or area of operation, e.g. operating inside a certain city.

1.2.2. On-demand public shared automated vehicles

On-demand public shared automated vehicles can provide consumers with on-demand door-to-door services and facilitate the sharing of travel costs among riders (Nemoto et al., 2021). It can be integrated with other urban transport modes, such as public transportation, to offer first/last-mile solutions in areas with low accessibility (Ainsalu et al., 2018; Fraedrich et al., 2019; Paddeu et al., 2021). On-demand public shared automated vehicles include demand-responsive or *para*-transit services, offering ridesharing without fixed timetables or routes, primarily funded by public sources (Winter et al., 2016). This service enables passengers from different origins and destinations to travel together in high-occupancy vehicles (Piatkowski, 2021; Winter et al., 2016). Individuals or groups can request trips to specific destinations via a mobile application.

1.2.3. Fleet-based shared automated vehicles

Fleet-based shared automated vehicles offer a cost-effective, demand-responsive door-to-door service facilitated by independent private companies (Levin et al., 2017). These vehicles provide two primary service models: carsharing and ridesharing. Carsharing caters to individuals or familiar groups utilising a private car, while ridesharing allows strangers with similar origins and destinations to share a ride at a reduced cost (Levin et al., 2017). Both models involve scheduling vehicles through a mobile application, relieving passengers of parking responsibilities. These services, be it carsharing or ridesharing, can complement traditional public transportation by serving as a substitute in areas with limited provision and where operating fixed-route transport is expensive (Piatkowski, 2021; Yap et al., 2016).

1.2.4. Privately owned automated vehicles

Privately owned automated vehicles are tailored for personal use. Compared to conventional personal cars, these automated vehicles are expected to enhance comfort, safety, and spaciousness, fostering increased productivity (Gelbal et al., 2017; Singleton, 2019). Additionally, this autonomy empowers owners to park their vehicles remotely (Schlossberg et al., 2018).

1.3. Current study

This study explores women's mobility needs and perspectives on automated vehicles. Employing a series of focus groups and in-depth interviews, we investigate the daily travel behaviour of women and the mobility challenges faced by this population group. Additionally, the study will delve into women's perceptions of visions and concerns regarding the future use of four different types of automated vehicles, as described in Section 1.2. Recognising that public acceptance plays an

important role in the widespread adoption of automated vehicles, a human-centred design approach is advocated for the successful proliferation of automated vehicles. This research sheds light on women's current mobility and how automated vehicles could fit into their mobility needs, investigating mobility visions as well as concerns associated with such vehicles. Prioritising women's perspectives in automated vehicle research is not only a matter of social justice but also a strategic step towards realising the full potential of this transformative technology. This study contributes to the understanding of these critical aspects, paving the way for a more inclusive and accessible future in the realm of automated vehicles.

2. Methodology

The study aims to understand how women might use automated vehicles in the future using focus group discussions and in-depth interviews. Therefore, we investigate women's (1) experience of current travel behaviour and perception of current mobility and (2) visions and concerns towards the adoption of different types of automated vehicles. The perspectives of general women were explored through three groups divided into focus groups. To explore scenarios specific to women with children and senior women, as well as their unique perspectives, we conducted in-depth interviews with women who have children and senior women. As previous studies have investigated the role of automated vehicles in relation to accessibility for seniors, this study targeted seniors who face fewer mobility challenges. Described as a small group with specific characteristics, a focus group facilitates qualitative data collection through discussions, aiding in a deeper understanding of a particular topic of interest (Krueger, 2014). Interviews allow for more in-depth exploration of individual perspectives, experiences, and opinions. The focus group discussions and interviews followed the same procedure and were conducted using the same interview questions as mentioned in the 2.2 Procedure. These two methods have previously been found to be effective in gaining insights into new transport solutions such as automated vehicles (Nordhoff et al., 2023; Pudāne et al., 2019; Trommer et al., 2016).

2.1. Participants

Focus group discussions and in-depth interviews were conducted between January and February 2023, with a total of 23 participants taking part in the study. Recruitment was conducted through personal networks and social media platforms. Thirteen participants were involved in three focus groups conducted at the TU Delft campus, with each group consisting of 4–5 participants. For women with children and seniors, online interviews were conducted online, taking into account temporal and spatial constraints. Gender, age, parental status, countries of residence, and possession of a driver's license are summarised in Table 1. All participants were female, with ten having a child and two being seniors aged 65 or older, and the average age is 34.5 (SD = 13.4) (One participant was unwilling to share age). Fifteen participants owned a car and used it as a driver to meet their daily needs. Nine participants reported having ridden in automated vehicles.

2.2. Procedure

The focus group discussions and interviews were semi-structured and proceeded in three parts. First, participants completed a questionnaire to gather demographic information, including countries of residence and family members. Next, participants engaged in open-ended questions about their experiences with mobility patterns (*'Please share your experience and thoughts on current mobility'*) in everyday scenarios such as commuting, night-time travel, remote area travel, and travelling with children (only those with a child). Subsequently, participants were provided with information about the types of automated vehicles as depicted in Fig. 1, which is modified from Faber and van Lierop (2020), and they were questioned about their expectations, concerns, and anticipated usage scenarios for each automated vehicle type (*'How will you use automated vehicles? How do automated vehicles change your mobility patterns? How could automated vehicles help with current mobility difficulties or improve mobility needs? Do you have any concerns about using automated vehicles?'*). In line with the semi-structured qualitative study (Longhurst, 2003), however, the interviewer asked follow-up questions to explore explanations for specific aspects raised by participants or to investigate new phenomena brought up by participants that were not initially addressed in the protocol. The focus group discussions were conducted offline, lasting between 70–90 min, and interviews were conducted online, lasting between 20–30 min. The content was recorded and transcribed for data analysis and identification of themes.

Table 1
List of participants' information.

Interview	Informant	Countries of residence (more than 1 year)	Child	Driving license
1	P1	USA	–	Y
2	P2	China, Netherlands	–	Y
3	P3	Cyprus, Italy, Netherlands, United Kingdom	–	Y
4	P4	China, Netherlands	–	Y
5	P5	Netherlands	–	N
6	P6	Denmark, Netherlands	–	N
7	P7	Germany, Netherlands	–	Y
8	P8	China, Italy, Netherlands	–	N
9	P9	Italy	–	N
10	P10	Korea, Netherlands	–	Y
11	P11	England, Netherlands	–	Y
12	P12	Netherlands, Spain	–	Y
13	P13	Netherlands, Turkey	–	Y
14	M1	Korea, Netherlands	One child	Y
15	M2	Korea, Netherlands	Two children	Y
16	M3	Korea, United Kingdom	One child	Y
17	M4	United Kingdom	Three children	Y
18	M5	Netherlands, Thailand	One child	Y
19	M6	Indonesia, Belgium, Netherlands	Two children	Y
20	M7	Korea, Netherlands	One child	Y
21	M8	Indonesia, Oman, Taiwan, United States	One child	Y
22	S1	Korea	Two children	Y
23	S2	Sweden	Two children	Y

*S1 and S2 are older than 65 years old.
**P1-P13 participated in focus group discussions and M1-M7 and S1-S2 participated in online interview.

2.3. Data analysis

We employed a thematic coding strategy proposed by Braun and Clarke (2006) to analyse the interview data. Initially, the authors read through all transcripts to become familiar with the data. During this stage, notes were taken on recurring themes and significant statements. Following this familiarisation phase, common themes were discussed and identified. Then, using ATLAS.ti ver 23.2.1, the authors conducted open coding on the transcripts. Each text segment was labelled with an initial code, which provided insights into vehicle type and mobility-related value (e.g., security, comfort) and travel situations (e.g., at night, with a child). The codes were not predetermined but were developed inductively from the data. The initial codes were then reviewed and refined through an iterative process. Similar codes were grouped together, and redundant codes were merged. Finally, coding data was merged using mobility types as a higher coding scheme to identify factors reflecting women's perspectives on current and automated mobility usage. While the results reported a number of mentions,

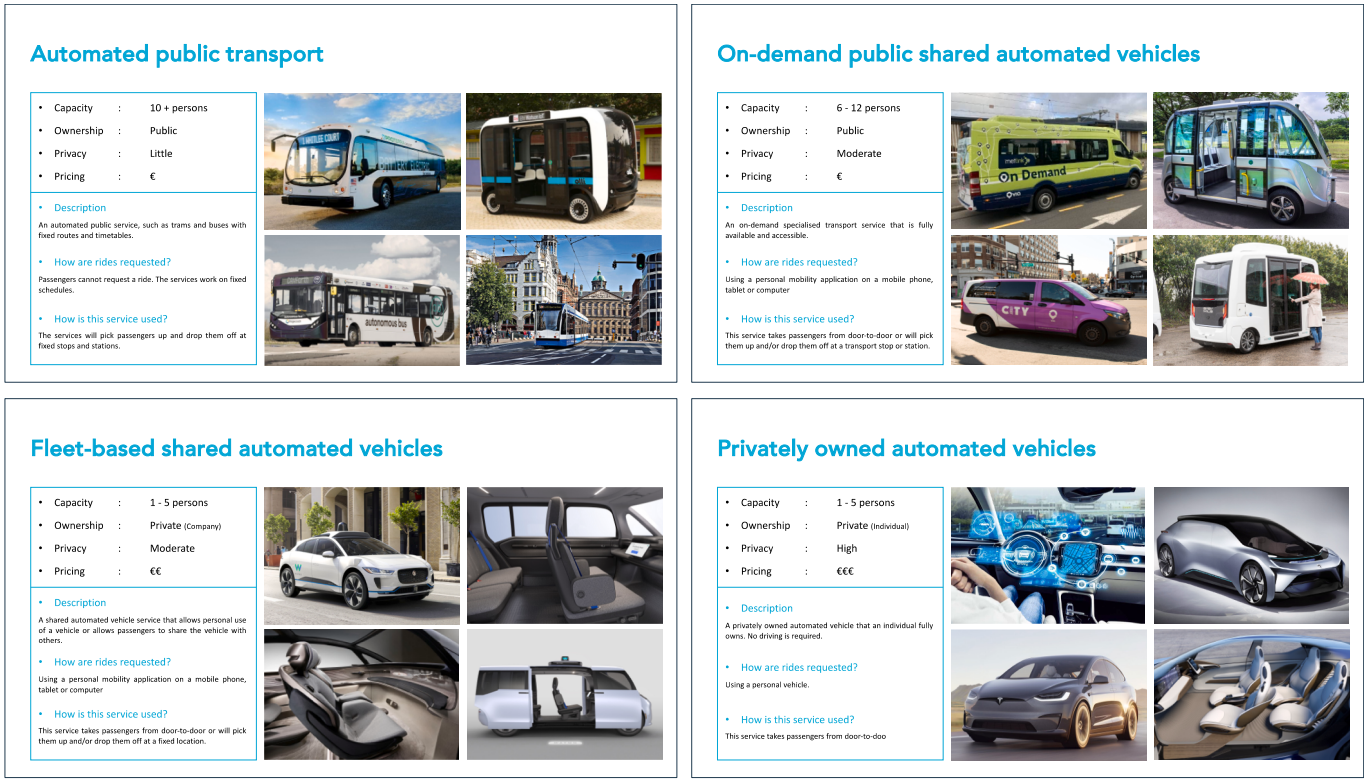

Fig. 1. Materials on four types of automated vehicles provided to participants, modified from Faber and van Lierop (2020).

this exploratory study focused on how these features are described among participants and how these perceptions of current mobility project the vision and concerns of automated vehicles.

3. Results

3.1. Reflect on current mobility

This section delves into the current landscape of mobility, particularly from the perspective of women. One of the challenges in automated vehicle research is the need to rely on participants' imagination to study perceptions and expectations of a mobility experience they have not yet encountered. Recognising that perceptions and expectations of future mobility are likely to be shaped by an understanding of the characteristics of the current mobility landscape and patterns, we explored the existing landscape as a basis for our investigation. Safety concerns are critical consideration factors, especially during night-time travels, encompassing worries about personal safety and the perceived vulnerability while waiting in stations, taking public transportation, or utilising shared transportation options like taxis. For mothers, mobility patterns undergo significant shifts post-baby, with the mother often assuming the primary caregiving role. This transition brings several considerations, from carrying essential items like snacks and baby supplies to planning restroom breaks and coordinating logistics, such as picking up and dropping off. The convenience and comfort offered by car travel, especially during the early stages of motherhood, emerge as a critical impact on their mobility experience and mobility pattern. Female seniors are known to tend to cease driving earlier than males (Gwyther & Holland, 2012; Hawley, 2021), and our study confirmed this through participant responses. Furthermore, the results demonstrate that stereotypes about female drivers persist and that awareness of these stereotypes influences women's driving attitudes. Below, we describe participants' current experiences and perspectives on each of the three mobility types.

3.1.1. Public transportation

3.1.1.1. Safety concerns. Participants emphasise concerns about their safety and comfort, especially when using public transportation at night:

> *Like [other] women, I probably worry more about safety … I would also not choose to use public transport after 8 or 9 PM. Because there will be fewer people. (P4)*

Participants echo common sentiments among women regarding safety, stating that they would avoid travelling alone at night unless necessary. If they need to use public transportation at night, P8 mentioned the importance of finding familiar faces on public transportation or swiftly relocating if encountering anxious individuals to ensure safety. P7 mentioned the preference for the bus over the subway due to the perceived accessibility to drivers, providing a sense of psychological reassurance regarding surveillance and potential intervention in emergencies. Overall, participants' transportation choices prioritise personal safety and the perceived level of monitoring, reflecting broader security concerns. In addition, participants considered the conditions of stations in terms of safety, which is aligned with Chowdhury and Van Wee (2020), who found that women experience anxiety while waiting for a vehicle at stations. While there was a difference between the preference for subway and bus stations, in common, they wanted stations that could be avoided in emergencies but were not exposed to potential danger. Additionally, P10 mentioned that perceived safety, along with convenience factors such as distance from home, was a determining factor in selecting the station to use, as follows.

> *… I live in between two tram stations. One is more crowded and has much more light at night. And the next station is less crowded and more dark. It's not safe to sit, but it's closer to my home. So, I always have to [consider to] choose between [two stations]. (P10)*

3.1.1.2. Scheduling challenges in public transportation. Most participants

expressed a reluctance towards multiple transfers or long-distance train journeys due to concerns about reliability.

> *I was looking up how many kilometres it is (from work) to my house, and it's less than 10 km … it should not take an hour to travel 9 km, but it does because there are all these little steps. (P11)*

This was attributed to the lack of control over schedules and the potential for extended travel times in case of delays or cancellations. In addition, S2 and M8, who live in a small town, said it is inconvenient that buses do not come often. Furthermore, P5 highlighted feeling anxious during rush hour due to a perceived inability to disembark from public transportation easily. Women's travel tends to involve shorter distances and durations compared to men's travel, yet women undertake a greater number of trips due to the need for multiple short trips and more frequent stops for household chores (Wu et al., 2021). Therefore, scheduling issues such as delays affect all passengers regardless of gender but have a greater impact on women's daily routines.

3.1.1.3. Using public transportation with a child. While the experience of public transportation varies depending on the infrastructure level of countries, with one participant mentioning no inconvenience while travelling with a baby, most participants noted that there were various elements to pay attention to when using public transportation with their children, as M2 stated.

> *If I take public transportation, then I have to carry a lot of stuff [for kids]. …Especially, it's not easy to take my kids to Rush Hour. It is like a … people's looking? I dragged the stroller and placed big places when there were a lot of people, and when the kids would get annoyed, make noise, or be rude to me, I would get nervous and look around. So, I would avoid public transportation. (M2)*

M3 mentioned that when using public transportation with a child, the participant planned more thoroughly to ensure the safest and most efficient route. This includes considering various factors, such as potential obstacles and maintenance when utilising public transportation with children.

Mothers become concerned about their child's safety when using public transportation with them. At the same time, when moving with their child, mothers may find it challenging to respond to risks due to several limitations compared to when alone. One participant mentioned considering various scenarios to ensure the child's safety in unexpected situations and noted increased sensitivity to potential risks. M1 shared an experience where safety was threatened while using the subway with her child, as follows.

> *I used the car more frequently because I had really bad experiences using public transportation with my child. … When my child was very young while returning home late at night with my child in a stroller, someone began following us from the subway. I was embarrassed. Due to the stroller, there was a limitation of movements, such as running away. Since then, I have not used public transportation for safety reasons. (M1)*

Inconveniences associated with using strollers on public transportation include difficulties in boarding and alighting, as well as limited stroller parking spaces. M8 mentioned inconvenience when manoeuvring with a stroller on trams or trains due to narrow doorways. However, buses were perceived as more accommodating due to their wider doors, accessibility of low-level buses, and drivers willing to wait for stroller users. Additionally, four participants noted that while buses offer stroller parking spaces, if there is no space available for parking the stroller due to another stroller or wheelchair, it can lead to inconveniences such as folding strollers.

3.1.2. Shared transportation – Taxi and ridesharing

As highlighted by several participants, most expressed apprehensions about taxi drivers due to unpleasant experiences, potential risks in enclosed spaces, or perceived stereotypes.

> *I had a lot of [experience that] they [male taxi drivers] that made me feel uncomfortable … they were bit weird…. [one time asked me to] sit in the front with him. (P7)*

> *If I take … Uber or a taxi … the reliability of the drivers influences me a lot … scores and also some comments, especially maybe I have more concerns for male [drivers]. That's not good to say, but I think that's my intuition. So, I prefer to choose female drivers at night. But during the day, I think it's not so much different. (P8)*

Consequently, five participants mentioned that they shared taxi information with friends or family when boarding a taxi, as P13 stated.

> *… what I've done with all my other girlfriends is that … when we're leaving each other at the end of the night, everyone gets into cabs, and we all share the cab license plate numbers with each other … So, this is kind of like a self-implemented security system that we've had for the last 15 years. (P13)*

In addition, participants found it uncomfortable to engage in conversation with taxi drivers or the fact that a taxi driver could listen to their private conversations. Two participants mentioned that they have a more defensive attitude when they are in a taxi with their child, as stated by M4. In addition, M6 expressed concern about disturbing other passengers when travelling with her child.

> *When Uber taxi drivers start chatting or listening when the family talks, I feel uncomfortable … when I take a taxi with a child, I tend to have a defensive attitude, so I am rather uncomfortable with talking. (M4)*

Furthermore, two participants mentioned that they prefer female taxi drivers, and one participant noted that she only accepts women when using ride-sharing apps, such as Blabla Car, due to past unpleasant experiences. However, one participant from Denmark recalled the positive image of a luxury vehicle taxi driver, portraying them as professional.

3.1.3. Private car

3.1.3.1. Perceived stereotype of women drivers. We asked focus group 3 (P10, P11, P12, and P13) about the stereotype of women drivers in their home country, and all four participants agreed that there is a stereotype – women are poor drivers, causing accidents (Moè et al., 2015). The discussion demonstrated the prevalent stereotypes surrounding women and driving, as well as the impact of these stereotypes on individuals' perceptions and behaviours.

> *I consider my family quite open-minded and progressive, but even my uncle would say like, 'Oh, of course, it's a woman driving. That's why they had an accident.' So, like as a bad driver (P12)*

> *I think we (South Korean) have a similar kind of concept, especially for middle-aged women. So, when there is an accident by those people (women), then … some less educated people will call … an accident happened because women were not in the home [women should only stay at home]. (P10)*

P11 and P13 highlighted the societal bias against women drivers, emphasising the misogyny inherent in such stereotypes. She mentioned how driving is often viewed as a masculine activity, with women being marginalised in this domain. Despite recognising the fallacy of these stereotypes, some individuals still find themselves affected by societal judgments, leading to feelings of anxiety and self-doubt while driving, as stated by P11. These mentions align with Gaymard et al. (2023) and Yeung and von Hippel (2008) that have shown how stereotypes influence the driving behaviour and attitudes of female drivers.

> *It (this stereotype) makes me anxious … Like I am assuming that I'm being judged automatically somehow … I don't really enjoy it(driving),*

but I'm very anxious when I do have to drive. And I think that part of it is I've almost internalised a little bit that I am less capable somehow inherently, which is not true. Because I see people… of all different genders driving terribly all the time. But yeah, somehow, a little bit of it is in my head already. You already have a somewhat assumption that people could think of me as a… Yeah, and then you start to believe it kind of a little bit or not believe it, but it's there in your head, and it affects the way you feel. (P11)

At the same time, P11 and P12 mentioned trusting female bus drivers more, believing that women are less prone to taking risks and driving more cautiously.

3.1.3.2. Private car needs and considerations for women with a child. After having a child, participants perceived a greater necessity for using a car. It happened due to heightened concerns about safety in public spaces, a desire to shorten travel time and ensure comfort during travel with a child, and additional considerations regarding their children's transportation needs, including drop-offs and pickups. Among the eight participants who have children, only one uses a bicycle as their primary mode of transportation, while the others primarily rely on cars. Three participants mentioned that they began using cars more frequently after having children, as stated by M2.

I considered the car as a major priority [transportation mode] when I went out with the kids … Even if people [who have a kid] did not have a car before, they consider buying a car after they have kids. (M2)

When travelling with their children by car, mothers experience a different journey compared to travelling alone. One of the most significant differences mentioned by all mothers (eight participants) was the increase in baggage.

I have a lot of supplies [when moving with kids]. Snacks, water… And then, when the children were younger, I had to carry around diapers, snacks, food, and milk. Even now … when I go with kids, I carry toys, books, water, snacks, wet wipes, and other things. Anyway, I have a lot of stuff. (M2)

Additionally, four participants who have a child mentioned that children often demand attention while in the car, requiring constant care in the back seat or even stopping the car to address their needs.

The child has a lot of requests in the car … when I take a car with a baby [without a partner], I couldn't listen to any of the kid's requests. Even if the kid was begging me to do something, or saying that kid was hungry, or that kid wanted to drink water, I couldn't respond to any of their requests. When it was too serious, I had to go to the rest area or find a place where I could stop the car … I was very stressed during driving. (M1)

3.1.3.3. Senior's private driving. Participants mentioned factors influencing individuals' decisions to continue or cease driving as they age. S1, aged 65, mentioned the following reasons for stopping driving and her current usage of driving when needed:

[I stopped driving when] I was in my early 50 s … [because] I felt difficulties in parking … When I was driving, I was scared of the car that was jumping in … [When I go somewhere] I mainly take public transportation … or [I asked] friends or my husband. (S1)

S2, aged 80, stated that she continues to drive except in adverse weather conditions or low visibility. However, she mentioned that her sister, who lives in a heavily congested metropolitan area, ceased driving due to safety concerns. Furthermore, P12 discussed gender differences in driving cessation, suggesting that women may stop driving earlier than men due to a sense of humility and concern about causing accidents.

3.2. Vision and concern for automated vehicles

Participants expressed a common expectation of comfort associated with automated vehicles. Safety concerns evident in current mobility were also reflected in automated vehicles. In addition, concerns regarding the automation of vehicles on roads, such as buses and cars, included technical issues like object detection technology and the implementation of interactions between current human drivers. This section describes participants' safety concerns and suggestions for safety enhancement for each type of automated vehicle, as well as expectations for mobility support for mothers and senior women.

3.2.1. Safety concerns in automated public transportation without drivers

Participants mentioned the benefits of automated vehicles, such as late-night travel, but also expressed safety concerns about using the vehicles with strangers without drivers.

Two participants mentioned the potential benefits of AV public transportation systems, particularly in enhancing reliability and improving availability, such as reducing short headway intervals or operating during limited service hours.

… the biggest impact would probably be…buses at night … in Milan, like after midnight, it really feels very, it's desolate, you see nothing, you have to wait probably one hour… and you also have to stay in the streets for a huge amount of time [for waiting]. So that would probably be the best benefit. (P9)

However, eight participants expressed apprehensions about crime and the lack of human intervention to address emergencies or ensure passenger safety, as stated by M1. Suggestions for enhancing safety included separate compartments with individual doors or communication systems between passengers and remote operators.

I'm most worried about the situation within the bus … especially in the late hours or early hours; for example, if a potential criminal were to get on the bus and I am the only one on the bus [and not the bus driver], I would be worried about that, so I don't think I would use the late hours or early hours. (M1)

Participants were concerned about safety, focusing on the absence of a human driver, especially in buses, where immediate assistance might be required or passengers felt vulnerable. The participants' responses reveal the role of drivers and the human interaction they provide in public transportation. P2 and M3 mentioned the flexibility drivers offer, such as waiting for passengers, which contributes to a sense of humanity and opening the back door when a passenger needs to taxi with a wheelchair or stroller. P4 expresses concern about the potential isolation that may arise as automation, referring to the current human interaction in public transportation, such as greeting between passengers and bus drivers. M4 participants who have a child emphasised the role of drivers in ensuring safety, particularly for passengers with strollers or wheelchairs, suggesting the implementation of visual or auditory cues to reassure passengers.

I've been on an autonomous tram in a different country in Europe. But I almost couldn't catch the moment when the door closed, so I was very anxious with the baby. I was really worried about it … For example, [automated public transportation can provide features] like a traffic light at the entrance, showing the time until it will be closed. There should be a lot of tools that give you visual or psychological safety. (M4)

3.2.2. Safety concerns in on-demand public shared automated vehicles

Participants had varied perceptions regarding the safety of on-demand public shared automated vehicles. It was evaluated as a mode between taxis and public transportation in terms of comfort and price for participants. As a result, M1 and S2 mentioned that it may not be as appealing if there is no significant cost advantage compared to taxis.

While some participants felt these vehicles were safer than

traditional public transportation, others perceived them as less secure due to their smaller and more enclosed spaces. Regarding vehicle safety, M1 suggested vehicle designs with security cameras inside and the ability to check the interior from the outside. Regarding the security cameras, some participants mentioned that cameras help enhance the perception of safety, while others stated that while having cameras is better than not having them, they may not feel significantly safer unless someone continuously monitors the footage. Furthermore, four participants expressed discomfort with the idea of using these vehicles with strangers but suggested that they would be positive if used with other passengers with similar interests, such as at specific events.

When describing the on-demand public shared automated vehicle, it was explained that it could be accessed via an app, and six participants perceived the use of vehicles through the app as positive in terms of safety. Participants mentioned that through the app, they could access information about the number and gender of passengers sharing the route and evaluate their evaluation by previously shared passengers before boarding the vehicle. One participant noted that ensuring identity verification during the app registration process serves as a filtering mechanism, emphasising that having passenger records in the app could enable post-incident actions if any event occurred. The desired information obtained through the app includes the number of passengers, gender, passenger ratings, travel routes, and estimated time to reach the destination. On the other hand, P4 and P5 expressed concerns about their information being exposed to other passengers through the app or during vehicle sharing, potentially being maliciously exploited.

3.2.3. Absence of drivers in fleet-based shared automated vehicles (driverless taxis)

While two participants mentioned feeling weird about no interaction with a taxi driver, most participants expressed a preference for driverless taxis over traditional ones, citing negative experiences with human taxi drivers. They value the autonomy and perceived safety provided by automated vehicles, especially considering concerns about crime and uncomfortable interactions with drivers.

> *Even if the price is higher than a taxi with a driver, I am willing to use an automated taxi. I am more worried about being a victim of a crime by people (drivers) than automation technology level. (M1)*

However, the need for coping mechanisms in the event of technical issues, such as an emergency button and remote phone call, was mentioned, along with the necessity for providing the traffic information traditionally obtained from taxi drivers, such as encountering traffic congestion due to accidents. In addition, three participants raised concerns about the cleanliness of automated vehicles, particularly due to the possibility of previous passengers leaving trash behind. They emphasised the importance of user experience design in ensuring a clean and pleasant environment inside the vehicle. P9 mentioned the implementation of systems where passengers could report the cleanliness of the vehicle, such as uploading photos after each ride.

3.2.4. Mobility support for women travelling with children

When travelling with children, mothers often contend with a multitude of belongings and considerations. Automated vehicles are seen as a potential solution to alleviate these challenges.

Regarding on-demand shared public automated vehicles, M3 mentioned that when transferring to different modes, including a car, carrying a car seat is an inconvenience and suggested that the shared vehicle would be helpful in alleviating such inconvenience.

> *I think it would be really good for kids … door-to-door. The biggest issue with having a baby in the car is that I have to install a car seat … But if my journey is not door-to-door, the car seat is pretty big … I can't carry it around. That's always an issue [to carry the car seat in the other transportation mode] … If this can be used as a door-to-door, and if the service itself is built into it, it will be very useful. (M3)*

Four participants with a child presented specific scenarios where private automated vehicles could be highly beneficial, such as paying attention to their children's needs while driving. They positively evaluated private automated vehicles, expecting that they could address their children's immediate demands while enhancing both safety and convenience.

> *.. I can use these functions when my child needs me in the middle of driving … and then I can do something that the child needs right now; I think this function will be very useful to me. (M2)*

3.2.5. Mobility support for senior women

Two seniors, despite currently having no physical mobility restrictions, expect automated vehicles to increase their freedom of mobility and consider it important.

S1 and S2 emphasised the practicality of using the on-demand public shared automated vehicle for casual tasks such as leisure activities with friends and shopping, suggesting potential cost savings.

> *I think it would be comfortable for me to go to a restaurant with my friends. … We can move one car instead of two or three cars, so we can save money and go to the place at the same time. (S1)*

In addition, S1 and S2 also expressed a positive outlook towards private automated vehicles. Perceived comfort and convenience associated with automated vehicles were anticipated to positively impact participants' mobility patterns, leading them to an anticipated increase in travel and engagement in personal activities. Additionally, participants expressed expectations that automated private vehicle technology could provide a safer and more reliable mode of transportation compared to their current driving experiences.

> *If I had a car like this, I would drive it. It will be so comfortable that I can move myself using my car. It will be so nice … I think it will change [my mobility pattern] a lot … I think I will travel more, and I can do my own hobby more. I will go to the market more often. (S1)*

> *It's (Private AV) very safe … I can go to Göteborg, Helsingborg, Malmö, just like a train. I will not be so tired … Maybe it might be safer driving than my age driver. (S2)*

4. Discussion

This study shed light on the multifaceted nature of mobility, particularly concerning the experiences and perspectives of women across different age groups and life stages. The comprehensive exploration of current mobility patterns and future expectations surrounding automated vehicles provides valuable insights into the evolving landscape of transportation, particularly regarding the diverse needs and concerns of women, parents, and seniors. The results showed that women positively perceive automated vehicles in terms of providing convenience and supporting mobility. Furthermore, design supports that address safety concerns will strengthen the acceptance and positive perception of automated vehicles. An inclusive approach ensures that women's unique needs and preferences are addressed, leading to safer, more accessible, and empowering mobility solutions for all. To achieve this, it is important to note that women's mobility can only be improved when the design of both the system and the physical vehicle is co-developed with women—particularly with mothers of young children and senior women. In this section, we discuss the results, the role of the automated vehicles, and design suggestions.

4.1. Ensuring safety

The study underscores the important role of safety in women's experience of transportation. Transport safety and security are critical factors in women's mobility choices (Bakran, 2018). Whether it's

concerned about personal safety when using public transport at night, feelings of vulnerability when travelling alone with children, or any other scenario, women consistently prioritise safety in their transportation decisions. The current perception of safety in using mobility services is also reflected in the vision and concerns regarding automated vehicles.

While participants expressed common expectations of comfort and convenience associated with automated vehicles, they also voiced concerns about safety, particularly in scenarios where human intervention may be required. Interestingly, concerns related to personal safety from other passengers in public transport and on-demand automated vehicles dominated over concerns about safety from technological incidents such as accidents. There were apprehensions about the absence of mediators in the event of incidents on public transport. There is already a security camera in public transport, but it has limited impact on alleviating women's fears compared to the presence of personnel (Gardner et al., 2017). Therefore, it appears imperative to incorporate features in the design of automated vehicles that ensure passenger safety, such as more proactive systems, emergency communication facilities, and real-time monitoring capabilities. While public transport drivers played a role in enhancing perceived safety, taxi drivers had a negative impact on perceived safety. Consequently, automated taxis, without drivers, were perceived positively by women in terms of safety. Therefore, automated taxis seem to be a good alternative in terms of perceived safety for women.

To mitigate technological concerns and enhance acceptance, there is a need for means through which passengers can receive information similar to what drivers traditionally provide. For instance, in the case of stroller usage, displaying the time until the door closes in public transport can alleviate concerns about door closure. Furthermore, providing information about a vehicle's driving behaviour or surrounding situations to passengers can enhance trust and acceptance (Kim et al., 2021). Concerns also arose, especially from seniors, about addressing technical issues in vehicles owned by others, such as taxis. Hence, there appears to be a need for channels to request assistance promptly in case of technical malfunctions.

4.2. Support women's mobility

Women's mobility is currently facing various challenges. Safety concerns during night-time travel, additional considerations such as carrying items and planning routes when mothers travel with their children, the decision of senior women to cease driving due to safety concerns and declining capabilities, and stereotypes of women drivers often pose significant hurdles.

Automated vehicles hold the potential to transform women's mobility. Firstly, automated vehicles expand options for night-time travel, offering a safer alternative. The extended operation of public transportation and fleet-based shared automated vehicles provide a secure option compared to traditional taxis. While there are safety concerns regarding driverless public transportation, as discussed in Section 3.1, various design options can be applied to overcome these challenges. Moreover, automated vehicles offer a safe and convenient mode of transportation, significantly reducing the burden on mothers. Specifically, private automated vehicles enable mothers to meet their children's needs without compromising safety, even during travel. Additionally, shared mobility facilitates door-to-door transportation, alleviating the burden of transitioning between different modes of transportation. Similarly, seniors view automated vehicles as enhancing mobility and independence. Adoption of automated vehicle technology could mitigate fears related to accidents or navigation issues associated with ageing. This would empower senior women to participate in social activities and confidently explore the world. Furthermore, automated vehicle technology presents an opportunity to redefine societal perceptions of driving capabilities, fostering confidence and empowerment among women and other marginalised groups. The persistent biases against women drivers underscore the importance of designing automated vehicles with inclusive interfaces and promoting gender-neutral messaging to combat stereotypes.

4.3. Limitations and further studies

In-depth research was conducted through interviews and focus group discussions to understand women's current mobility and their concerns and visions regarding automated vehicles. Due to the exploratory nature of this study, there are several research limitations to consider for future research.

First, our study includes participants from diverse backgrounds; however, this diversity also means that participants' responses regarding mobility reflect their cultural backgrounds and the context of their residence countries. The same experiences, thus, are perceived relatively. For example, a participant who has lived in the United Kingdom mentioned that the Netherlands is relatively safe, while a participant who has lived in China expressed that the Netherlands is relatively unsafe. Nevertheless, the results of the study focus on the common themes mentioned by women, which we consider within cultural contexts, emphasising that the results include universal perspectives of women regardless of their backgrounds. Additionally, the sample size for the elderly was small. As accessibility, a critical factor in elderly mobility has been explored in the previous study (Faber & van Lierop, 2020) using the same methodology, we did not investigate this aspect deeply. Instead, we examined how women's early driving give-up and fear of driving due to ageing are reflected in current mobility usage and expectations regarding autonomous vehicles. Future studies could delve deeper into these aspects, focusing exclusively on elderly women, to explore design guidelines. In addition, participants' statements about automated vehicles may be based on several assumptions and may have discrepancies with the actual usage of automated vehicles. For instance, participants without driving licenses or those who have discontinued driving expected an expansion of mobility through automated vehicles without considering restrictions such as regulations concerning driver's licenses. While the vision proposed for automated vehicles in this study may not be met due to regulatory or technological limitations, we can still confirm the positive impact of automated vehicles on women's mobility through the study. While automated vehicles offer a novel approach, there are other solutions. However, automated vehicles present a unique opportunity for designers, policymakers, planners, and other stakeholders to prioritise women's inclusion and safety right from the outset. By integrating gender-sensitive design principles and safety features into automated vehicle development, a transportation system can be created that meets the diverse needs of women and enhances their mobility experience. Additionally, considering alternative modes of transportation alongside automated vehicles (e.g., multimodal and intermodal trip planning) can provide a comprehensive approach to improving women's overall mobility and experienced accessibility in urban environments.

In future research, applying the same methodology to male participants and comparing the results would be interesting. Currently, we only reported on women's perspectives; comparing them with male perspectives could reveal gender-emphasized perspectives versus universal perspectives. Additionally, there is a need to develop design guidelines for automated vehicles. Interaction design studies influencing actual behaviour and perceptions could be conducted in the future. In exploring solutions for women's mobility challenges, some issues can also be addressed through improvements to existing transportation modes and travel networks.

5. Conclusion

This study contributes to a broader understanding of women's needs and desires regarding mobility and transportation. In particular, perceptions of current mobility are projected onto automated vehicles,

manifesting as both visions and concerns. This study highlights women's concerns about the safety of driverless public transport, as emphasised in previous studies, while also demonstrating a positive perspective on the safety of automated vehicles, such as driverless taxis. Additionally, it presents expectations for how automated vehicles could improve mobility for women with kids or elderly women who are more likely than males to give up driving voluntarily. By understanding and addressing the diverse needs and experiences of women in the transportation sector, policymakers and stakeholders can strive to create a more equitable and sustainable mobility system for the future.

CRediT authorship contribution statement

Soyeon Kim: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Shabila Anjani:** Writing – review & editing, Methodology, Data curation. **Dea van Lierop:** Writing – review & editing, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

We deeply appreciate the participants who voluntarily participated in this study to improve women's mobility.

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