Transportation Research Part A 150 (2021) 385–397

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Autonomous vehicles and mobility for people with special needs

Eva Kassens-Noor [a,b,*], Meng Cai [a], Zeenat Kotval-Karamchandani [a], Travis Decaminada [a]

[a] School of Planning, Design, and Construction, Michigan State University, 552 W Circle Drive, East Lansing, MI 48823, USA
[b] Global Urban Studies Program, Michigan State University, 447 Berkey Hall, East Lansing, MI 48823, USA

ARTICLE INFO

Keywords:
Autonomous public transit
Special needs
Perception
Willingness to ride
Mobility restricted
Visual impaired

ABSTRACT

Large mobility gaps exist between people with and without disabilities. People with special needs are heavily dependent upon public transportation for their essential needs. Autonomous vehicles (AVs) have the potential to increase mobility for these populations. However, they have been largely absent from AV perception research. To fill this gap, we analyzed their perceptions, willingness to use, and concerns over autonomous public transit (APT) based on an on-board intercept survey of 1861 current bus riders in Michigan, with 40% having some type of special needs. We found significant differences among different special needs groups. While respondents who were visually impaired, mobility restricted, or with multiple accommodation needs were more likely to rely on public transit than those without any special needs, their willingness to use APT varied. Respondents with visual impairment were more likely, but riders with mobility disabilities were less likely to be willing to use APT. In addition, our survey results suggest that respondents with special needs perceive AVs primarily negatively. This was especially true for mobility-restricted groups. Furthermore, there were differences in bus riders' reasons not to use APT. Compared to respondents without special needs, those with multiple accommodation needs hold concerns over APT's safety more, while respondents with mobility disabilities were more likely to distrust AV technology. This study advances our understanding of different special needs populations' perception and acceptance of APT, providing support to policymakers in developing inclusive policies and practices that would bring the promised benefits of AVs to these populations.

1. Introduction

Over one billion people, or 15% of the world population, have some form of disability (World Health Organization, 2018). According to a representative survey of disabled adults in the US, 34% of them cope with the problem of inadequate transportation access (Taylor et al., 2010). Though there have been improvements in the incorporation of the needs of disabled populations in the past two decades, large gaps still exist between people with and without impairments in their mobility options (Taylor et al., 2010). People with special needs have unique transportation needs and face significant barriers in reaching essential services and living an independent life (Litman, 2017b; Wong et al., 2018; Yigitcanlar et al., 2019). For example, their healthcare needs are often not met due to these barriers, and they suffer as a result (Jones et al., 2018).

* Corresponding author at: School of Planning, Design, and Construction, Michigan State University, 552 W Circle Drive, East Lansing, MI 48823, USA.
E-mail addresses: ekn@msu.edu (E. Kassens-Noor), caimeng2@msu.edu (M. Cai), kotvalze@mail.msu.edu (Z. Kotval-Karamchandani).

https://doi.org/10.1016/j.tra.2021.06.014
Received 6 September 2020; Received in revised form 20 May 2021; Accepted 15 June 2021
Available online 4 July 2021

Autonomous vehicles (AVs) have the potential to improve the quality of lives for people with special needs (Hwang et al., 2020; (Bradshaw-Martin and Easton, 2014; Dianin and Cavallaro, 2019; Fagnant and Kockelman, 2015; Bjelčić and Švelec, 2019; Bennett et al., 2019a; Litman, 2017a; Claypool et al., 2017; Brewer and Kameswaran, 2018; Harper et al., 2016). However, special needs populations are frequently overlooked in the automated mobility transformation with few exceptions (Harper et al., 2016; Bennett et al. 2019a). Some studies have analyzed the impact that AVs will have on the lives of people with special needs (Chan, 2017; Claypool et al., 2017), but very few have asked how they actually perceive AVs. Studies that do focus on special needs groups t often select one special need over others (Bennett et al., 2019a, 2019b; Brinkley et al., 2017); whether or not, and to what extent, different perceptions exist among special needs populations remains unknown. Moreover, most studies on disabled populations discussed AVs in general (Bennett et al., 2019a, 2019b; Brinkley et al., 2017) rather than autonomous public transit (APT), even though many people with special needs rely on public transport services (Jolly et al., 2006).

We aim to fill the gap in the existing literature by focusing on the *different* special need's populations and their perceptions and acceptance of APT. Our conceptual framework is based on the social model of disability, which defines the term as a social rather than a medical problem (Oliver, 1996). While AVs are developed to solve accessibility barriers due to impairments that may involve health-related medical conditions, the social model suggests that disabilities are socially caused; that is, because society stigmatizes people with disabilities thereby creating physical and social barriers. As such, gathering the perceptions, opinions, and viewpoints of people with different disabilities is essential in identifying potential socially-caused problems introduced by the advent of autonomous mobility. Thus, we conducted an on-board intercept survey with 1861 current public transit riders across Michigan, a state in the US, of which 40% had some type of special need, to address key questions related to autonomous mobility: Does and if so, how does willingness to use, perceptions, and concerns about autonomous public transit vary among special needs populations depending upon their disability? And are these characteristics related to their dependence on public transit.

This study contributes to the literature by providing insight into understudied special needs populations through the largest on-board intercept survey dataset on public transit rider perceptions on APT in the US. In addition, our analysis differentiates populations with different special needs, highlighting their differences in perceptions, willingness to use, and concerns over APT.

2. Mobility for people with special needs

It is estimated that between 10 and 20% of a given, typical, North-American adult population cannot or should not drive due to physical, economic constraints, age, or vehicle failures (Litman, 2017b). Since automobile dependence is a common characteristic of typical American cities, non-drivers are often presented with few transportation alternatives while at the same time bear the economic, social, and environmental costs created by drivers (Litman and Brenman, 2012). Recently, several North American cities have begun integrating social equity into their transportation plans, with a few specifically mentioning special needs populations, though some of these plans lack clear priorities or follow-through (Manaugh et al., 2015).

2.1. Reliance on public transit

People with special needs, those with disabilities, and the elderly all frequently rely on public transportation (Jolly et al., 2006; Litman, 2017b; Wong et al., 2018). In the average North American city, around 3–5% of the population are adults who cannot drive due to a disability (Litman, 2017b). These populations are often dually burdened by their disability and low incomes, which can be even further exacerbated as a result of living in sprawling suburbs (Zhao and Gustafson, 2013). Public transportation may be the only means for these people to live independently (Carmien et al., 2005). Enabling public transit networks to better suit the needs of disadvantaged people may not only increase the use and efficacy of public transit systems, but also its equity (Ferrari et al., 2014).

Lack of mobility for special needs populations leads to a significant decrease in their quality of life (Lucas and Musso, 2014). Further, transportation barriers can have significant impacts on a person's health, especially for the disadvantaged (Syed et al., 2013). Special needs populations may have significantly more healthcare needs than non-disadvantaged populations (Pollard Jr et al., 2014), which often remain unmet (Jones et al., 2018). Special needs populations are also heavily dependent upon public transportation for healthcare appointments, a lack of which increases their likelihood to delay or forgo care (Syed et al., 2013); This is especially true for people living with psychological disabilities (Stock et al., 2011). This leads us to our first hypothesis:

Hypothesis 1. Bus riders with special needs rely more on public transit than those without special needs.

2.2. Emerging mobility technology

Some forms of modern technology have increased mobility among special needs populations. For example, cell phone apps in conjunction with GPS technology, can help navigate people with special needs on public transit systems (Barbeau et al., 2010), and rideshare services help further increase their mobility, particularly for the blind (Bleach et al., 2020). However, populations that lack access to smartphones, or the ability to use them, may not benefit from these technologies (Fetni, 2019). Nonetheless, there is a push to persuade rideshare companies to expand their programs to those with special needs, and some cities subsidize the costs for special needs people to use rideshare services (Schwieterman and Livingston, 2018).

AVs in particular may play a major role in increasing mobility for special needs populations (Litman, 2017a; Millard-Ball, 2018). AVs have the potential to significantly increase employment opportunities among disabled people, as well as increase their ability to reach essential services; this facet of the discussion is becoming a major part of policy discussions regarding AVs (Claypool et al., 2017).

However, the impact of AVs, and how they are to be implemented, is still subject to a myriad of planning, political, technological, and ethical debate (Beiker, 2012; Litman 2017a, 2017b; Awad et al., 2018; Pearl 2019). Ultimately, because personal mobility has such a significant bearing on the quality of one's life, from an ethical standpoint, policymakers are being strongly urged to include people with special needs in their discussions regarding AVs (Litman 2017a, 2017b). Recent findings suggest that people with disabilities may be discriminated against when attempting to purchase or operate an AV, either by the laws that govern them or by the vehicles' systems themselves (Trewin, 2018). Further, understanding the perceptions and willingness to ride of special needs populations, and what requirements they may have, is not well studied. Special needs populations vary widely in their transit accommodations and can be grouped broadly into mobility restricted, vision impaired, hearing impaired, and those with psychiatric disabilities.

2.2.1. *Mobility restricted*

An intelligent transportation system that includes AVs would provide mobility-restricted populations with a greater means to travel, as well as increase overall road safety and equity (Bennett et al., 2019; Harper et al., 2016; Doecke et al., 2015; Shrestha, 2020). Personal mobility is also strongly correlated with one's ability to drive a vehicle and/or access to adequate transportation (King et al., 2011). The loss of autonomy leads to a decrease in quality of life, and these populations also view current public transportation options to be inadequate; though it has not been specifically studied, AVs may allow these people greater autonomy and thus a greater quality of life (Lucas and Musso, 2014). Additionally, an increase in transportation options for mobility restricted populations may even have a significant impact on consumer spending (Das et al., 2017). Ultimately, mobility-restricted people's attitudes toward AVs are not entirely clear. If the benefits of an AV and the ease of its use are persuasive, mobility restricted populations may be more inclined to ride in an AV.

2.2.2. *Vision impaired*

Rideshare services do help fill mobility gaps for the visually impaired, though younger people are more likely to use them than are the elderly (Bleach et al., 2020). Trust in rideshare apps, and specifically the drivers, varies and is built over time; though the same is true for most technologies created/marketed to visually impaired people (Brewer and Kameswaran, 2019). Autonomous seeing eye robots are already being developed to assist the vision-impaired; in the future, visually impaired people may be even more accustomed to autonomous technology than others (Galatas et al., 2011). The same technology that powers AVs also can/is being used to assist the visually impaired in navigating the world (Martinez et al., 2017). Finally, as AVs become more ubiquitous the likelihood exists that visually impaired populations will benefit from and interact with AVs.

2.2.3. *Hearing impaired*

Similar to other special needs groups, the hearing impaired often have difficulty navigating public transportation, and are not always adequately planned for (Fürst, 2010), they too may suffer health consequences as a result of transportation barriers (Pollard Jr et al., 2014), and AVs may have the potential to improve their mobility. One of the core complications that could prevent the hearing impaired from operating AVs is the user interface. Though, design recommendations are being made to push AV manufacturers to keep hearing impaired people in mind (Ferati et al., 2017). Thankfully, technologies do exist, and more are being developed, that allows the hearing impaired to better communicate with/operate their vehicles (Jia et al., 2018). Sign language could even be used to operate an AV if necessary (Kamat et al., 2016). Because of the potential for an increased quality of life hearing impaired people may be more inclined to travel in an AV.

2.2.4. *Psychiatric disabilities*

In areas without adequate public transportation, psychologically impaired people may suffer a significant decrease in quality of life, and AVs could potentially help. Some individuals with psychological disabilities do drive, though less often than non-disadvantaged people; AVs could increase theirs and others road safety (Beiker, 2012). Because people with psychological disabilities are often low-income, the potential for shared AVs could lower the cost to the point that they too can benefit from the technology (Metz, 2018). Ultimately, people with psychological disabilities may be more accepting of AVs, and more eager to ride in them.

2.3. *Perceptions of autonomous vehicles and willingness to ride*

People with special needs stand to benefit significantly from AVs. These populations may even see the largest increase in miles traveled compared to other groups; upwards of a 14% increase (Harper et al., 2016). People with disabilities were found to be willing to pay a significantly larger price for an AV, likely due to the technologies perceived usefulness to them (Shabanpour et al., 2018). However, research has also found that compared to people without disabilities, mobility-restricted people may experience more anxieties on AV safety-related issues (Bennett et al., 2019b; Hwang et al., 2020) and their willingness to ride in AVs was lower (Kassens-Noor et al., 2020). Those suffering from visual impairments report being eager for fully autonomous vehicles, indicating that the technology would provide them with greater independence, and even save them money (Brewer and Kameswaran, 2018). People with cognitive disabilities appear more than willing to ride in an AV; when their opinion on the technology was analyzed 46% of respondents reported that the idea of AVs gave them a sense of freedom, and 20% reported a sense of curiosity (Bennett et al., 2019a). This brings us to our second hypothesis:

Hypothesis 2. Willingness to use APT varies with the type of disability a rider has.

Willingness to use and perception are closely related and perceptions of AVs are influenced by age, gender, and social status. From

the perspective of other road users, AVs are viewed as relatively low risk, though acceptance again varies with age and gender; younger people, and particularly males, view AVs more favorably than other demographics (Hulse et al., 2018; Kassens-Noor et al., 2020). Additionally, familiarity with the technology impacts perception (Lee et al., 2017). Researchers have not synthetically articulated the different perceptions or concerns about AVs attributed to different disabilities. To the best of our knowledge, only four other studies explicitly focused on special needs populations regarding their attitudes towards AVs and one considered the variable of disabilities in the analysis (Table 1).

Previous studies analyzed special needs populations jointly (Hwang et al., 2020) or selected one special need over others (Bennett et al., 2019a, 2019b; Brinkley et al., 2017). This may be due to the methodological difficulties in accessing special needs groups given their unique circumstances (Sorensen, 2006).

Some disabled people may perceive AVs as neutral or negative: these fears likely come from a lack of perceived control (Bennett et al., 2019b). Fears surrounding perceived safety, control, and trust appear to be the leading causes of negative attitudes towards AVs, and emotion plays a significant role in these concerns (Pettigrew et al., 2019). Similarly, special needs populations may experience anxiety related to AVs (Hwang et al., 2020). Despite being excited about the technology, some visually impaired people are concerned that AVs are not being developed with their needs in mind, and that they may not be able to effectively operate them (Brinkley et al., 2017). Thus, perceptions towards AVs are mixed among the general population *and* those with disabilities. This brings us to our last set of hypotheses:

Hypothesis 3. There is no difference in AV perceptions among bus riders with differing special needs.

And thus,

Hypothesis 4. There is no difference in concerns over APT among bus riders with varying special needs.

3. Methodology

In total, 1861 responses to an on-board intercept survey of current public transit were collected from riders across the State of Michigan, which is, to the best of the authors knowledge, the largest on-board intercept survey dataset on public transit riders' attitudes towards AVs in the US (dataset made available with this publication). The response rate was 86.7%, which is satisfactory for generalizability and very high for in-person surveys (Johnson, 2003).

3.1. Materials

The survey itself was part of a state-wide and publicly funded study which sought to assess customer satisfaction and trip purposes of public transit riders. As a means to measure reliance on public transit we asked riders if public transit were not available, how would they reach their destination? This question allowed respondents to select multiple answers, including "not make this trip," "look for alternative destinations," "get a ride from family or friends," "take a taxi/cab/Uber/Lyft," "drive," "walk/bike," and "other." When a respondent answered, "not make this trip," we considered them to be dependent on public transportation. Thus, we define reliance on public transit by whether or not a rider had an alternative mode of travel. Further, respondents were also given a definition of AVs as "busses/shuttles/cars that operate without a driver." After this definition they were asked about their perception of AVs via an open-ended question: how they feel about AVs? We asked if they would ride in an autonomous shuttle or bus if their transit agency used some AVs as part of their fleet of vehicles. This question prompted them to select either "yes" or "no." If a rider chose "no," they were then asked a follow up open-ended question: what their main concerns would be that would stop them from riding in AVs? Finally, basic socio-demographic information, including employment status, gender, age, annual household income, race/ethnicity, and special accommodation needs were collected. It is important to note that the special needs question allowed for multiple selections, which included no special needs, blindness/ visual impairment, deaf/ hard of hearing, mobility disabilities, psychiatric disabilities, and other.

Table 1
Literature on disabled populations' attitudes towards AVs.

Study	Sample	Location	Method	Finding
Brinkley et al. (2017)	People with visual disabilities	Florida, US	Focus group	Participants were optimistic about the benefits of AVs but concerned about their needs not being adequately addressed in AV development and potential legal liability.
Bennett et al. (2019)	People with mobility disabilities	UK	Interview	Two-thirds of the disabled respondents were negative or ambivalent towards AVs. Their attitudes were influenced by their interest in technologies, anxiety, intensity of disability, knowledge in AVs, internal locus of control, and action orientation.
Bennett et al. (2019)	People with intellectual disabilities	UK	Interview	Desire for freedom and fears about travelling in AVs determined individuals' willingness to use AVs.
Hwang et al. (2020)	People with mobility or visual disabilities	Texas, US	Focus group	Participants had doubts about the accessibility and effectiveness of AV transportation services to expand their mobility options.
Kassens-Noor et al. (2020)	Public transit users	Michigan, US	Survey	Demand-response public transit users with mobility disabilities were significantly less willing to ride in AVs than those without mobility disabilities.

3.2. Data collection

Passengers were sampled from 26 different public transit agencies across the state of Michigan from January 2019 to February 2020. Two research assistants conducted the in-person survey in coordination with each agency on three days from 8 am to 5 pm. The study was approved by the Institutional Review Boards of a Tier 1 research university and the surveyors received training for research involving human subjects.

Two research assistants rode transit vehicles separately, on different routes and vehicles, asking every adult passenger if they would like to take the paper survey. They read the surveys aloud to 15.1% of respondents due to the rider's limitations, and if necessary, wrote their answers for them. If a passenger suggested they were not able to complete the questionnaire during the ride, the surveyors offered the rider a pre-paid return envelope to mail in the paper survey at any time. This scenario rarely occurred. In total, we received 1861 responses.

3.3. Respondents

Respondent demographics are listed in Table 2. Females constituted 56.70% of the respondents, 21.25% were 65 years or older, and 72.34% came from a family with an annual household income of less than $20,000. More than half (59.12%) of the respondents indicated that they were unemployed. The majority (69.27%) of respondents were Caucasian and 19.48% were African American. About three-fifths (59.67%) of the respondents did not have any special needs; one-third (33.66%) had one disability or accommodation that required assistance with; the remaining 6.67% indicated that they had multiple accommodation needs.

3.4. Data analysis

Responses to the two open-ended questions were coded manually and labeled with different themes found via emergent coding and

Table 2
Socio-demographic characteristics of survey respondents.

	Respondents with no special needs Count (%)	**Respondents with special needs** Count (%)	**Total responses** Count (%)	**Non-response** Count	**Total**
Gender			**1672 (100)**	189	**1861**
Male	420 (45.65)	241 (39.38)	724 (43.3)		
Female	500 (54.35)	371 (60.62)	948 (56.7)		
Age			**1736 (100)**	125	**1861**
18 to 24	176 (18.49)	30 (4.66)	215 (12.38)		
25 to 34	179 (18.8)	65 (10.09)	265 (15.26)		
35 to 54	287 (30.15)	185 (28.73)	519 (29.9)		
55 to 64	149 (15.65)	178 (27.64)	368 (21.2)		
65 to 74	115 (12.08)	101 (15.68)	229 (13.19)		
75 to 84	36 (3.78)	57 (8.85)	99 (5.7)		
85 and older	10 (1.05)	28 (4.35)	41 (2.36)		
Annual household income			**1439 (100)**	422	**1861**
Less than $5,000	219 (26.16)	137 (26.15)	377 (26.2)		
$5,000 to $9,999	136 (16.25)	125 (23.85)	276 (19.18)		
$10,000 to $14,999	132 (15.77)	105 (20.04)	252 (17.51)		
$15,000 to $19,999	77 (9.2)	53 (10.11)	136 (9.45)		
$20,000 to $24,999	91 (10.87)	36 (6.87)	137 (9.52)		
$25,000 to $34,999	77 (9.2)	25 (4.77)	105 (7.3)		
$35,000 to $49,999	48 (5.73)	23 (4.39)	75 (5.21)		
More than $50,000	57 (6.81)	20 (3.82)	81 (5.62)		
Employment status			**1695 (100)**	166	**1861**
Employed	505 (53.5)	130 (21.17)	693 (40.88)		
Unemployed	439 (46.5)	484 (78.83)	1002 (59.12)		
Race			**1663 (100)**	198	**1861**
African-American/ Black	207 (22.14)	95 (15.08)	324 (19.48)		
Caucasian/ White	612 (65.45)	481 (76.35)	1152 (69.27)		
Other	116 (12.41)	54 (8.57)	187 (11.24)		
Accommodations, disabilities, or special needs 1619 (100)				242	**1861**
No special needs	–	–	966 (59.67)		
Blindness/ visual impairment (single disability)	–	–	42 (2.59)		
Deaf/ hard of hearing (single disability)	–	–	29 (1.79)		
Mobility disabilities (single disability)	–	–	275 (16.99)		
Psychiatric disabilities (single disability)	–	–	106 (6.55)		
Other accommodation needs (single disability)	–	–	93 (5.74)		
Multiple accommodation needs	–	–	108 (6.67)		

then organized into categories (Charmaz, 2008). The coded responses, together with the choice responses, were then subject to statistical analyses. Binomial and ordinal logistic regression models were used to determine if the observed differences were statistically significant. We processed data and performed analysis using R.

4. Autonomous mobility for people with special needs

The results of our survey suggest that bus riders with special needs are more likely to rely on public transit than those without special needs. This is especially true for those, who were vision impaired, mobility restricted, or with multiple accommodation needs. When controlling for other socio-demographic factors, we further found that bus riders with visual impairment were more likely, while riders with mobility disabilities were less likely, to be willing to use APT than those without special needs. However, whether a rider relied on bus services was *not* associated with one's willingness to ride in autonomous buses when controlling for demographics. Notably, special needs groups perceive AVs primarily negatively raising concerns over safety, absence of human interactions, and technological fears.

4.1. Dependence on public transit

The percentage of respondents dependent upon public transit were noticeably higher among those with special needs. While 31.56% of our survey respondents reported that they would not be able to make their trips if public transit was not available, the number for respondents with some kind of special needs was 42.72% −17.67 percentage points higher than that of respondents without any special needs (25.05%).

Respondents with special needs were statistically significantly more likely to be dependent on public transit ($p < 0.001$). The percentage of respondents relying on public transit was especially high among those who were vision impaired, mobility restricted, and /or had multiple accommodation needs (Table 3). Results from a logistic regression model show that these differences were statistically significant when controlling for other socio-demographic factors (Table 4). The odds of a bus rider with visual impairment, mobility disabilities, and multiple accommodation needs being dependent on public transit was 3.31, 1.80, and 2.62 times greater than that of a rider without special needs, respectively.

4.2. Willingness to ride in autonomous public transit

Respondents' willingness to use APT was associated with their accommodation needs, but not with whether or not they were dependent on public transit. In general, 45.67% of respondents with special needs would like to ride in AVs if given the opportunity, but percentages varied greatly among respondents with different types of disabilities (Table 3). Holding other factors constant, respondents with visual impairment were statistically significantly more likely to be willing to ride in autonomous buses (Table 5); the odds were 2.82 times greater than that of a respondent with no special needs. In contrast, respondents with mobility disabilities were less likely to be willing to use AVs; the odds were 0.63 less than that of someone without special needs. We did not find a statistically significant difference between respondents with hearing impairment, psychiatric disabilities, or multiple special needs. While cognitive lock-in can cause people to remain loyal to a habit or preference (Murray and Häubl, 2007), we found that whether a respondent depends on public transit did not add significant explanatory power to their willingness to use AVs beyond socio-demographic characteristics.

4.3. Perceptions on autonomous public transit

The majority of respondents with special needs perceived AVs negatively, whereas less than one-fourth perceived them positively. When asked how people with special needs felt about AVs, 56.08% of respondents provided a negative answer (Table 6). Some respondents expressed their concerns over safety, others were against AVs because of the potential costs, including the elimination of a human driver and job loss. One rider with mobility restrictions explained: "No-not with handicapped riders who may need assistance after falls." Only 22.69% were optimistic about AVs. They considered AVs to be something "cool" and were looking forward to the deployment of autonomous buses. The remaining 21.23% responses were neutral or neutralized such as "need careful limits, see much potential."

Table 3
Respondents relying on public transit and willing to ride in AVs.

Accommodations, disabilities, or special needs	Relying on public transit Count (%)	Willing to ride in AVs Count (%)
No special needs	232 (25.05)	488 (53.80)
Blindness/visual impairment (single disability)	23 (54.76)	24 (61.54)
Deaf/hard of hearing (single disability)	9 (32.14)	7 (26.92)
Mobility disabilities (single disability)	118 (44.70)	95 (37.40)
Psychiatric disabilities (single disability)	36 (36.00)	52 (53.06)
Other accommodation needs (single disability)	31 (34.83)	44 (51.76)
Multiple accommodation needs	50 (49.02)	52 (53.06)

Table 4
Binomial logistic regression of respondents relying on public transit.

	β	Std. error	e^{β}
(Intercept)	−1.63***	0.27	0.20
Blindness/visual impairment (base: no special needs)	1.20**	0.44	3.31
Deaf/hard of hearing (base: no special needs)	−0.03	0.48	0.97
Mobility disabilities (base: no special needs)	0.59**	0.18	1.80
Psychiatric disabilities (base: no special needs)	0.32	0.27	1.37
Other accommodation needs (base: no special needs)	0.53	0.29	1.70
Multiple accommodation needs (base: no special needs)	0.96***	0.26	2.62
Gender: female (base: male)	0.26	0.14	1.30
Age	0.11*	0.05	1.12
Income	−0.03	0.03	0.97
Employed (base: unemployed)	−0.40*	0.16	0.67
Race: Caucasian (base: African-American)	0.43*	0.18	1.54
Race: other (base: African-American)	−0.01	0.27	0.99
N	1181		
AIC	1391.9		
McFadden pseudo-R^2	0.38		

Signif. code: <0.001*** <0.01** <0.05*.
Notes: We measured age and income in ordinal levels and treated them as continuous variables in our modeling.

Table 5
Binomial logistic regression of respondent's willingness to use APT.

	β	Std. error	e^{β}
(Intercept)	1.33***	0.25	3.77
Blindness/ visual impairment (base: no special needs)	1.04*	0.48	2.82
Deaf/ hard of hearing (base: no special needs)	−0.68	0.50	0.51
Mobility disabilities (base: no special needs)	−0.46*	0.19	0.63
Psychiatric disabilities (base: no special needs)	0.22	0.26	1.25
Other accommodation needs (base: no special needs)	0.06	0.29	1.06
Multiple accommodation needs (base: no special needs)	0.27	0.26	1.32
Gender: female (base: male)	−0.41**	0.12	0.67
Age	−0.21***	0.05	0.81
Income	0.02	0.03	1.02
Employed (base: unemployed)	−0.02	0.14	0.98
Race: Caucasian (base: African-American)	−0.53***	0.16	0.59
Race: other (base: African-American)	−0.33	0.23	0.72
Rely on public transit: yes (base: no)			
N	1160		
AIC	1554.7		
McFadden pseudo-R^2	0.36		

Signif. code: <0.001*** <0.01** <0.05*.

When comparing perceptions of AVs between respondents with and without special needs, we found that there was no statistically significant difference between groups. However, when considered separately, respondents with mobility disabilities were statistically significantly more likely to provide negative responses (Table 7). Their odds of being more positive about AVs were 60% greater than that of respondents without any accommodation needs when holding other socio-demographic factors constant.

4.4. Reasons against autonomous public transit

Among respondents with special needs who were not willing to ride in autonomous buses, about one-third (32.21%) stated that safety was their main concern. Many respondents simply wrote down "safety" or "accidents," while others mentioned more specific safety issues such as mechanical failures, hacking, or computer malfunctions. Another overlapping, interrelated reason for rejecting AVs was technological fears. 16.26% of respondents suggested that they would not consider the current technology to be reliable or trustworthy. For example, one respondent with mobility impairment noted "electronics break down too easily." A lack of human interactions and personal service on AVs also concerned respondents. 17.18% of responses fell into this category. A few respondents with accommodation needs mentioned that they would need/prefer human assistance, e.g. "people need special treatment for special needs," and "have a seizure and no one there."

We further found that there was a statistically significant difference in respondents' reasons not to use APT between riders with different special needs (Table 8). In particular, respondents with multiple special needs were more likely to be concerned about AVs' safety ($p < 0.05$); their odds were 2.25 times greater than that of someone with no special needs. In addition, respondents who were mobility-restricted were more likely to reject AVs due to distrust in technology ($p < 0.01$); their odds were 2.56 times greater than that

Table 6
AV perceptions of respondents with special needs.

	Vision impaired	Hard of hearing	Mobility disabilities	Psychiatric disabilities	Other	Multiple disabilities	Total
	Count (%)	Count (%)	Count (%)	Count (%)	Count (%)	Count (%)	Count (%)
Negative	**18 (46.15)**	**16 (66.67)**	**144 (63.16)**	**40 (44.44)**	**42 (55.26)**	**49 (52.13)**	**309 (56.08)**
Negative simple responses	14 (35.9)	11 (45.83)	116 (50.88)	27 (30)	32 (42.11)	41 (43.62)	241 (43.74)
Safety concerns	2 (5.13)	–	15 (6.58)	10 (11.11)	6 (7.89)	4 (4.26)	37 (6.72)
Cost concerns	2 (5.13)	5 (20.83)	13 (5.7)	3 (3.33)	4 (5.26)	4 (4.26)	31 (5.63)
Neutral	**7 (17.95)**	**6 (25)**	**47 (20.61)**	**23 (25.56)**	**13 (17.11)**	**21 (22.34)**	**117 (21.23)**
Positive	**14 (35.9)**	**2 (8.33)**	**37 (16.23)**	**27 (30)**	**21 (27.63)**	**24 (25.53)**	**125 (22.69)**
Positive simple responses	14 (35.9)	2 (8.33)	32 (14.04)	27 (30)	20 (26.32)	21 (22.34)	116 (21.05)
Benefits	–	–	5 (2.19)	–	1 (1.32)	3 (3.19)	9 (1.63)

Table 7
Ordinal logistic regression of respondents' perceptions on AVs.

	β	**Std. error**	**e^{β}**
(Negative|Neutral)	−1.44***	0.24	0.23
(Neutral|Positive)	−0.39	0.24	0.66
Blindness/visual impairment (base: no special needs)	0.37	0.43	1.45
Deaf/hard of hearing (base: no special needs)	−0.54	0.49	0.58
Mobility disabilities (base: no special needs)	−0.51**	0.19	0.60
Psychiatric disabilities (base: no special needs)	0.16	0.25	1.17
Other accommodation needs (base: no special needs)	−0.12	0.29	0.89
Multiple accommodation needs (base: no special needs)	0.10	0.25	1.11
Gender: female (base: male)	−0.40***	0.12	0.67
Age	−0.18***	0.05	0.83
Income	−0.01	0.03	0.99
Employed (base: unemployed)	−0.13	0.14	0.88
Race: Caucasian (base: African-American)	−0.66***	0.16	0.52
Race: other (base: African-American)	−1.44	0.24	0.70
N	1058		
AIC	2132.34		
McFadden pseudo-R^2	0.34		

Signif. code: <0.001*** <0.01** <0.05*.

of a respondent without any special needs. We did not find a statistically significant difference in respondents' concerns over the lack of human interaction among riders with and without special needs.

5. Discussion

We analyzed 1861 responses to an on-board intercept survey on travel needs and perceptions, conducted in conjunction with 26 transit agencies in the state of Michigan. About 40% of the respondents in this study are those with special needs/accommodations. This study aimed to assess the dependency of riders, specifically those with special needs, on public transit and perceptions of AVs, used both as public transit and personal vehicles in general.

Overall, results indicate that there is significant difference among riders with various special needs. Confirming our first hypothesis, binomial logistic regressions indicate that riders with all types of special needs are more dependent/reliant on public transportation compared to those without special needs, but those riders with visual impairment, mobility disabilities and multiple accommodation needs were statistically significantly more dependent on public transit. For the second hypothesis, we indeed found that willingness to use APT varies with the type of disability a rider has. Binomial logistic regressions indicate that riders with visual impairment are statistically significantly more willing to ride in APT than those with no special needs while other special needs groups were either not statistically significant or were less willing to ride in APT. However, neither our third nor our fourth hypothesis could be confirmed, because there are differences in the perception of AVs and in the concerns over APT between riders with and without special needs. Ordinal logistic regressions indicate that riders with mobility disabilities are statistically significantly more negative towards AVs than

Table 8
Binomial logistic regression of reasons not to use APT.

	Safety concerns			Lack of human			Technological fears		
	β	Std. error	e^{β}	β	Std. error	e^{β}	β	Std. error	e^{β}
(Intercept)	−1.35***	0.41	0.26	−1.94***	0.50	0.14	−2.06***	0.54	0.13
Blindness/ visual impairment (base: no special needs)	0.39	0.81	1.47	−14.15	545.57	0.00	0.25	1.11	1.28
Deaf/ hard of hearing (base: no special needs)	−1.07	0.79	0.34	0.00	0.68	1.00	0.96	0.63	2.60
Mobility disabilities (base: no special needs)	0.10	0.26	1.10	−0.38	0.32	0.68	0.94**	0.30	2.56
Psychiatric disabilities (base: no special needs)	0.49	0.40	1.64	0.75	0.44	2.11	0.08	0.53	1.08
Other accommodation needs (base: no special needs)	0.18	0.46	1.19	−0.02	0.53	0.98	0.28	0.59	1.33
Multiple accommodation needs (base: no special needs)	0.81*	0.38	2.25	−0.87	0.63	0.42	−1.46	1.04	0.23
Gender: female (base: male)	0.11	0.19	1.12	0.19	0.25	1.22	−0.42	0.24	0.66
Age	−0.17*	0.08	0.84	0.11	0.09	1.12	−0.06	0.10	0.94
Income	0.12**	0.05	1.13	−0.01	0.06	0.99	−0.05	0.06	0.95
Employed (base: unemployed)	0.41	0.23	1.51	−0.32	0.29	0.72	0.71*	0.29	2.02
Race: Caucasian (base: African-American)	0.71*	0.29	2.04	−0.02	0.34	0.98	0.59	0.37	1.80
Race: other (base: African-American)	0.31	0.39	1.35	0.31	0.46	1.36	0.92*	0.47	2.50
N	563			563			563		
AIC	714.57			514.08			508.83		
McFadden pseudo-R^2	0.35			0.35			0.34		

Signif. code: <0.001*** <0.01** <0.05*.

those without special needs, while the other disabilities have mixed, albeit non-significant results. Similarly, binomial logistic regression results indicate that riders with multiple special needs were concerned with safety and those with mobility disabilities were more concerned with the distrust in technology, compared to those without special needs. Thus, our study confirmed hypotheses one and two, and rejected hypotheses three and four.

The percentage of respondents who rely on public transit was especially high among bus riders who were vision impaired, mobility restricted, and/or with multiple accommodation needs; their odds of having public transit as the only option for reaching their destinations were twice or three times greater than that of a rider without special needs. This finding aligns with Jolly et al.'s (2006) analysis of disabled people's usage of public transit in Britain. The essential role of public transit playing in special needs populations' life is not surprising given the background that many of them are non-drivers or do not have access to private vehicles (Syed et al., 2013). Our results verified the findings from previous research that many people with a disability were dependent on public transit. However, less than half of them would be open to the idea of riding in APT, resulting from a mix of fear and distrust in this emerging technology that could potentially bring them greater mobility freedom. This indicates a lack of effort in involving and engaging special needs populations in the transformation of our transportation systems towards AVs.

While we hypothesized that bus riders with special needs would be more willing to use APT given the literature on the promised benefits of AVs (Claypool et al., 2017), our survey results suggested that indeed riders with visual impairment were much more likely but those with mobility disabilities were less likely to adopt APT than people without special needs; the remaining special needs groups, including individuals with hearing difficulties, psychiatric disabilities, or those who have multiple special needs, were not statistically significantly different from those without any special needs in their willingness to use APT. The high willingness to adopt APT among vision-impaired riders may be explained by Brinkley et al.'s (2017) focus group study, in which they found that participants who were blind or of low vision were overwhelmingly excited and optimistic about the independence and mobility that AVs would bring. Another explanation could be that people with vision impairments tend to be more familiar with new mobility services like ridesharing and assistive technologies like robotic navigation aids (Bleach et al., 2020; Galatas et al., 2011; Hwang et al., 2020), given that familiarity and awareness leads to increased acceptance (Gkartzonikas and Gkritza, 2019). In contrast, respondents with mobility disabilities showed relatively low interest in riding in APT, which is consistent with our findings on their predominantly negative perceptions on APT. The theory of cognitive lock-in, which argues that repeated experience could cause people to become locked in to things that they are more familiar with (Murray and Häubl, 2007), may explain the difference in AV acceptance among different populations.

In general, bus riders with special needs held more negative than positive perceptions towards APT. This was especially true for riders who were mobility restricted. A survey of 444 people with ambulatory disabilities in the United Kingdom reached similar conclusions that two-thirds of their respondents were negative or ambivalent about AVs (Bennett et al., 2019b). Compared to the findings from a focus group on APT with visual or mobility disabled participants (Table 1), instead of enthusiasm and concerns about APT's accessibility, our respondents raised more concerns over safety. This may be due to different respondents' profile (various disabilities vs. visual or mobility disabilities), study locations (Michigan vs. Texas), and methods (on-board intercept surveys vs. focus groups).

While concerns over safety, absence of human interactions, and technological fears were the major reasons that would stop bus riders with special needs from riding in autonomous buses, we further found that there was a difference in concerns between bus riders with and without special needs. More specifically, respondents with multiple accommodation needs were more likely to have doubts about APT's safety than those without special needs, and respondents with mobility disabilities were more likely to express their

distrust in technology. This is a novel finding as none of the previous studies on disabled populations' perceptions on AVs (Bennett et al., 2019a, 2019b; Brinkley et al., 2017; Hwang et al., 2020) made quantified comparisons among people with different special needs.

6. Conclusion

This study uncovers unique disparities in the reliance on public transit and the perceptions towards AVs and APT among those with varying disabilities. Bus riders who were visually impaired were more likely to be dependent on public transit and open to the idea of autonomous buses. Similar to the vision-impaired, a great number of people with multiple special needs relied on public transit to get around. However, instead of high acceptance of APT, they were more likely to be concerned about APT's safety than those without special needs. People with mobility disabilities were, on the other hand, concerned more about the technology not being reliable, and thus showed relatively low acceptance and negative perception of APT.

Our findings have important implications for policy and practice as there exist noteworthy differences between different special needs groups. The proposed solution to the problem of the social model of disability (Oliver, 1996) involves social policy change, e.g., the passage of the Americans with Disabilities Act, acknowledging the different needs of various disabilities towards finding autonomous mobility solutions. AV's are similar in that legislation and policies will need to be passed in order ensure that the most vulnerable members of our society are neither taken advantage of nor neglected as a result of a change in the landscape of mobility; that they have the same access to transportation as others. By better understanding how disadvantaged groups perceive APT we can more effectively create and alter polices to ensure that the maximum good is being done. Without perception studies highlighting the differences between special needs groups, all groups may be lumped together when policies are being drafted, which may lead to even more strife and inequality.

This study has shown that lumping people with disabilities into one group is a substantial error as different disabilities require different vehicles, different communication and engagement strategies, and different solutions to everyday travel needs. Further, transportation plans must consistently have a special focus on equity and those with different disabilities as their needs for travel are unique yet are often sidelined in practice. Further, there is an apparent lack of reliable and representative data for people with special needs. Thus, people with disabilities should be featured with greater representativeness and distinction in national datasets. As AVs become ready for deployment, policymakers and public transit service providers should actively incorporate the concerns of people with disabilities tailor services and communication strategies to involve and engage special needs populations in the transformation towards autonomous transit, to provide improved mobility and accessibility.

Despite the recent growing attention, people with disabilities are still largely absent from mainstream research on public perceptions of AVs. Future research should focus more on people with special needs, especially the differences in acceptance and attitudes among these populations. While our study provides evidence and analysis into their points of view, clearly there is much work to be done to better understand their opinions and needs. Even national datasets, the 2017 National Household Travel Survey (NHTS) for example, is not suitable/usable to study transit riders with special needs. Going forward, given the various disability combinations possible, more in-depth research is needed to differentiate their differing perspectives and needs.

Our study, however, also has some important limitations. As with all surveys, our questions suffered from non-response (Table 2), but we did not see a systematic pattern to the non-responses. A socio-demographic profile of bus riders in Michigan is non-existent, thus we were not able to inspect our sample with regard to its representativeness. Further, about one-third (31.42%) of the respondents who chose not willing to ride in AVs did not provide a reason, which may influence the validity of our findings on concerns over APT. Moreover, we were not able to determine the causes of respondents concerns about AVs, which could be due to their special needs or driven by media coverage. Finally, there could be a difference in people reliance on public transit, e.g., those who could not make it to a doctor's appointment without bus services and those who had to cancel a trip for recreation.

Funding sources

This research has been funded by the Michigan Department of Transportation.

CRediT authorship contribution statement

Eva Kassens-Noor: Supervision, Conceptualization, Writing - review & editing, Funding acquisition. **Meng Cai:** . **Zeenat Kotval-Karamchandani:** Investigation, Data curation, Writing - review & editing, Funding acquisition. **Travis Decaminada:** Methodology, Investigation, Writing - original draft.

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.

Appendix

Survey questions

1. If public transit was not available, you would:

a. Not make this trip
b. Look for alternative destinations
c. Get a ride from family or friends
d. Take a taxi/cab/Uber/Lyft
e. Drive
f. Walk/bike
g. Other: Please specify _____

Autonomous vehicles (AVs) are busses/shuttles/cars that operate without a driver.

2. How do you feel about autonomous vehicles?

_____

1. Would you ride in an autonomous shuttle/bus if your transit agency used some AVs as part of their fleet of vehicles? Please circle one:

YES NO

If no, what would be your main concerns stopping you from riding in AVs?
_____

3. Which one of the following best describes you? are you (circle only one):

a. Employed for pay outside your home
b. Self-employed
c. Student
d. Homemaker
e. Unemployed
f. Retired

4. Are you?

a. Male
b. Female
c. Other/Prefer not to answer

5. What is your age?

a. 18 to 24
b. 25 to 34
c. 35 to 54
d. 55 to 64
e. 65 and older

6. What is your total combined annual household income?

a. Less than $5,000
b. $5000 to $9,999
c. $10,000 to $14,999
d. $15,000 to $19,999
e. $20,000 to $24,999
f. $25,000 to $34,999
g. $35,000 to $49,999
h. $50,000 to $74,999
i. $75,000 to $100,000
j. More than $100,000

7. Which do you consider yourself:

a. African-American/Black
b. Asian
c. Caucasian//White
d. Hispanic/Latino(a)
e. Native-American Indian
f. Pacific Islander/Hawaiian
g. Other:_____

8. What accommodations, disabilities, or special needs do you require assistance with?

a. I do not have any special needs/I do not require any accommodations
b. Blindness/Visual impairment
c. Deaf/Hard of hearing
d. Mobility disabilities
e. Psychiatric disabilities
f. Other:_____

References

Awad, E., Dsouza, S., Kim, R., Schulz, J., Henrich, J., Shariff, A., Bonnefon, J.F., Rahwan, I., 2018. The moral machine experiment. Nature 563 (7729), 59–64.

Barbeau, S.J., Winters, P.L., Georggi, N.L., Labrador, M.A., Perez, R., 2010. Travel assistance device: Utilising global positioning system-enabled mobile phones to aid transit riders with special needs. IET Intel. Transport Syst. 4 (1), 12–23.

Beiker, S.A., 2012. Legal aspects of autonomous driving. Santa Clara L. Rev. 52, 1145.

Bennett, R., Vijaygopal, R., Kottasz, R., 2019a. Willingness of people with mental health disabilities to travel in driverless vehicles. J. Transp. Health 12, 1–12. https://doi.org/10.1016/j.jth.2018.11.005.

Bennett, R., Vijaygopal, R., Kottasz, R., 2019b. Attitudes towards autonomous vehicles among people with physical disabilities. Transp. Res. Part A: Policy Practice 127, 1–17. https://doi.org/10.1016/j.tra.2019.07.002.

Bjelčić, N., Švelec, D., 2019. New perspectives for people with special needs according the development of new generation ICT technologies.. In: 42nd International Convention on Information and Communication Technology: Electronics and Microelectronics (MIPRO), May. IEEE, pp. 392–397.

Bleach, K., Fairchild, N., Rogers, P., Rosenblum, L.P., 2020. Improving Transportation Systems for People with Vision Loss. American Foundation for the Blind, p. 20.

Bradshaw-Martin, H., Easton, C. (2014). Autonomous or 'driverless' cars and disability: A legal and ethical analysis. Eur. J. Curr. Legal Issues, 20(3), Article 3. http://webjcli.org/article/view/344.

Brewer, R.N., Kameswaran, V., 2018. Understanding the Power of Control in Autonomous Vehicles for People with Vision Impairment. In: Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 185–197. https://doi.org/10.1145/3234695.3236347.

Brewer, R.N., Kameswaran, V., 2019. Understanding trust, transportation, and accessibility through ridesharing. In: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, pp. 1–11.

Brinkley, J., Posadas, B., Woodward, J., Gilbert, J.E., 2017. Opinions and Preferences of Blind and Low Vision Consumers Regarding Self-Driving Vehicles: Results of Focus Group Discussions. In: Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 290–299. https://doi.org/10.1145/3132525.3132532.

Carmien, S., Dawe, M., Fischer, G., Gorman, A., Kintsch, A., Sullivan Jr, J.F., 2005. Socio-technical environments supporting people with cognitive disabilities using public transportation. ACM Trans. Computer-Human Interact. (TOCHI) 12 (2), 233–262.

Chan, C.-Y., 2017. Advancements, prospects, and impacts of automated driving systems. Int. J. Transp. Sci. Technol. 6 (3), 208–216. https://doi.org/10.1016/j.ijtst.2017.07.008.

Charmaz, K., 2008. Grounded Theory as an Emergent Method. In: Handbook of Emergent Methods. The Guilford Press, p. 16.

Claypool, H., Bin-Nun, A., Gerlach, J. (2017). Self-driving Cars: The Impact on People with Disabilities (p. 35) [The Ruderman White Paper]. Securing America's Future Energy & Ruderman Family Foundation.

Das, S., Sekar, A., Chen, R., Kim, H.C., Wallington, T.J., Williams, E., 2017. Impacts of autonomous vehicles on consumers time-use patterns. Challenges 8 (2), 32.

Dianin, A., Cavallaro, F., 2019. Automation and urban transport planning: policy recommendations and best practices. WIT Trans. Ecol. Environ. 238, 627–638.

Doecke, S., Grant, A., Anderson, R.W., 2015. The real-world safety potential of connected vehicle technology. Traffic Injury Prev. 16 (suppl. 1), S31–S35.

Fagnant, D.J., Kockelman, K., 2015. Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. Transp. Res. Part A: Policy Practice 77, 167–181. https://doi.org/10.1016/j.tra.2015.04.003.

Ferati, M., Murano, P., Giannoumis, G.A., 2017. Universal design of user interfaces in self-driving cars. Int. Conf. Appl. Human Factors Ergonom. 220–228.

Ferrari, L., Berlingerio, M., Calabrese, F., Reades, J., 2014. Improving the accessibility of urban transportation networks for people with disabilities. Transp. Res. Part C: Emerg. Technol. 45, 27–40.

Fetni, M. L. (2019). Development of a mobile application for carpooling the elderly [PhD Thesis]. MINISTRY OF HIGHER EDUCATION.

Fürst, E. (2010). Mobility barriers in urban transport for the sight or hearing impaired: Solutions help all passengers. na.

Galatas, G., McMurrough, C., Mariottini, G.L., Makedon, F. (2011). eyeDog: An assistive-guide robot for the visually impaired. In: Proceedings of the 4th International Conference on PErvasive Technologies Related to Assistive Environments - PETRA '11, 1. https://doi.org/10.1145/2141622.2141691.

Gkartzonikas, C., Gkritza, K., 2019. What have we learned? A review of stated preference and choice studies on autonomous vehicles. Transp. Res. Part C: Emerg. Technol. 98, 323–337. https://doi.org/10.1016/j.trc.2018.12.003.

Harper, C.D., Hendrickson, C.T., Mangones, S., Samaras, C., 2016. Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions. Transp. Res. Part C: Emerg. Technol. 72, 1–9.

Hulse, L.M., Xie, H., Galea, E.R., 2018. Perceptions of autonomous vehicles: Relationships with road users, risk, gender and age. Saf. Sci. 102, 1–13.

Hwang, J., Li, W., Stough, L., Lee, C., Turnbull, K., 2020. A focus group study on the potential of autonomous vehicles as a viable transportation option: Perspectives from people with disabilities and public transit agencies. Transp. Res. Part F: Traffic Psychol. Behaviour 70, 260–274. https://doi.org/10.1016/j.trf.2020.03.007.

Jia, J., Dong, X., Lu, Y., Qian, Y., Tang, D., 2018. Improving Deaf Driver Experience Through Innovative Vehicle Interactive Design. Int. Conf. Des. User Experience Usabil. 257–269.

Johnson, T. (2003). Survey Response Rate Reporting in the Professional Literature. 7.
Jolly, D., Priestley, M., Matthews, B. (2006). Secondary analysis of existing data on disabled people's use and experiences of public transport in Great Britain. 98.
Jones, M., Morris, J., Deruyter, F., 2018. Mobile healthcare and people with disabilities: Current state and future needs. Int. J. Environ. Res. Public Health 15 (3), 515.
Kamat, R., Danoji, A., Dhage, A., Puranik, P., Sengupta, S., 2016. MonVoix-An Android Application for hearing impaired people. J. Commun. Technol. Electron. Comput. Sci. 8, 24–28.
Kassens-Noor, E., Kotval-Karamchandani, Z., Cai, M., 2020. Willingness to ride and perceptions of autonomous public transit. Transp. Res. Part A: Policy Practice 138, 92–104. https://doi.org/10.1016/j.tra.2020.05.010.
King, M.D., Meuser, T.M., Berg-Weger, M., Chibnall, J.T., Harmon, A.C., Yakimo, R., 2011. Decoding the Miss Daisy Syndrome: An examination of subjective responses to mobility change. J. Gerontol. Soc. Work 54 (1), 29–52.
Lee, C., Ward, C., Raue, M., D'Ambrosio, L., Coughlin, J.F., 2017. Age Differences in Acceptance of Self-driving Cars: A Survey of Perceptions and Attitudes. In: Zhou, J., Salvendy, G. (Eds.), Human Aspects of IT for the Aged Population. Aging, Design and User Experience. Springer International Publishing, pp. 3–13. https://doi.org/10.1007/978-3-319-58530-7_1.
Litman, T., 2017a. Autonomous Vehicle Implementation Predictions. Victoria Transport Policy Institute Victoria, Canada.
Litman, T., 2017b. Introduction to Multi-modal Transportation Planning. Victoria Transport Policy Institute, Canada.
Litman, T., Brenman, M., 2012. A New Social Equity Agenda for Sustainable Transportation. Victoria Transport Policy Institute Victoria, Canadá.
Lucas, K., Musso, A., 2014. Policies for social inclusion in transportation: An introduction to the special issue. Case Stud. Transp. Policy 2 (2), 37–40.
Manaugh, K., Badami, M.G., El-Geneidy, A.M., 2015. Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. Transp. Policy 37, 167–176.
Martinez, M., Roitberg, A., Koester, D., Stiefelhagen, R., Schauerte, B., 2017. Using technology developed for autonomous cars to help navigate blind people. In: Proceedings of the IEEE International Conference on Computer Vision Workshops, pp. 1424–1432.
Metz, D., 2018. Developing policy for urban autonomous vehicles: Impact on congestion. Urban Science 2 (2), 33.
Millard-Ball, Adam, 2018. Pedestrians, autonomous vehicles, and cities. J. Plan. Educ. Res. 38 (1), 6–12.
Murray, K.B., Häubl, G. (2007). Explaining Cognitive Lock-In: The Role of Skill-Based Habits of Use in Consumer Choice (SSRN Scholarly Paper ID 964189). Social Science Research Network. https://papers.ssrn.com/abstract=964189.
Oliver, M., 1996. The social model in context. In: Understanding disability. Palgrave, London, pp. 30–42.
Pearl, T.H., 2019, January. Compensation at the crossroads: autonomous vehicles and alternative victim compensation schemes. In: Proceedings of the 2019 AAAI/ACM Conference on AI, Ethics, and Society, pp. 187–193.
Pettigrew, S., Worrall, C., Talati, Z., Fritschi, L., Norman, R., 2019. Dimensions of attitudes to autonomous vehicles. Urban Plann. Transp. Res. 7 (1), 19–33.
Pollard Jr, R.Q., Betts, W.R., Carroll, J.K., Waxmonsky, J.A., Barnett, S., deGruy III, F.V., Pickler, L.L., Kellar-Guenther, Y. (2014). Integrating primary care and behavioral health with four special populations: Children with special needs, people with serious mental illness, refugees, and deaf people. Am. Psychol., 69(4), 377.
Schwieterman, J.P., Livingston, M. (2018). Uber economics: Evaluating the monetary and nonmonetary tradeoffs of TNC and transit services in Chicago, Illinois.
Shabanpour, R., Golshani, N., Shamshiripour, A., Mohammadian, A.K., 2018. Eliciting preferences for adoption of fully automated vehicles using best-worst analysis. Transp. Res. Part C: Emerg. Technol. 93, 463–478.
Shrestha, K. (2020). 5G: The Fututre of Improved Road Safety and Autonomous Vehicles.
Sorensen, B.V. (2006). Populations with Special Needs (ORNL/TM-2006/559; p. 30). Oak Ridge National Laboratory.
Stock, S.E., Davies, D.K., Wehmeyer, M.L., Lachapelle, Y., 2011. Emerging new practices in technology to support independent community access for people with intellectual and cognitive disabilities. NeuroRehabilitation 28 (3), 261–269.
Syed, S.T., Gerber, B.S., Sharp, L.K., 2013. Traveling towards disease: Transportation barriers to health care access. J. Community Health 38 (5), 976–993. https://doi.org/10.1007/s10900-013-9681-1.
Taylor, H., Krane, D., Orkis, K., 2010. The Kessler Foundation/NOD 2010 Survey of Americans with Disabilities. Harris Interactive, p. 27.
Trewin, S., 2018. AI fairness for people with disabilities: Point of view. ArXiv Preprint. ArXiv:1811.10670.
Wong, R.C.P., Szeto, W.Y., Yang, L., Li, Y.C., Wong, S.C., 2018. Public transport policy measures for improving elderly mobility. Transp. Policy 63, 73–79. https://doi.org/10.1016/j.tranpol.2017.12.015.
World Health Organization. (2018). Disability and health. https://www.who.int/news-room/fact-sheets/detail/disability-and-health.
Yigitcanlar, T., Mohamed, A., Kamruzzaman, M., Piracha, A., 2019. Understanding transport-related social exclusion: a multidimensional approach. Urban Res. Policy 37 (1), 97–110. https://doi.org/10.1080/08111146.2018.1533461.
Zhao, F., Gustafson, T., 2013. Transportation Needs of Disadvantaged Populations: Where, When, and How? Federal Transit Administration, United States.