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Promoting Inclusive Design and Deployment of Connected and Automated Vehicles for Older Adults Through Education of Engineering Students

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FINAL REPORT

by

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16. Abstract
16. Abstract The development of connected and automated vehicles (CAVs) holds promise for reducing traffic crashes and maintaining mobility among older adults. Challenges remain, however, in ensuring that CAVs are accessible, acceptable, affordable, and otherwise inclusive for older adults. The objective of this project was to increase graduate students' awareness of and sensitivity to these issues, using a framework of experiential learning. The project provided an opportunity for University of Michigan (U-M) students enrolled in a graduate course on human-centered design and engineering to be involved in all four aspects of experiential learning – exploring, engaging, reflecting, and communicating – to meet the project objective. The project involved several primary tasks: 1) completion of a research synthesis on older adults and CAVs by the project team; 2) discussions between the project team and older adults themselves (termed community engagement); 3) presentations by the project team to students in the class on the project background, findings from the research synthesis and community engagement, and an industry perspective on older adults and CAVs; 4) implementation of student classroom projects on older adults and CAVs as part of their regular course curriculum; 5) development of posters by the students highlighting their classroom projects; 6) presentation of the posters by the students in a formal poster session at the University of Michigan Transportation Research Institute targeted to U-M faculty and staff, representatives from industry, and other undergraduate and graduate students; 7) evaluation through pre- and post-surveys of students to measure changes in knowledge about older adults and CAVs; and 8) development of a set of recommendations for future efforts to train and educate students in this area, as well as the design and deployment of CAVs themselves. Findings are discussed for each of these tasks.

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1. INTRODUCTION

The development of connected and automated vehicles (CAVs), poised to be one of the most transformative transportation advances in recent history, holds promise for reducing traffic crashes and maintaining mobility among older adults. Once fully automated CAVs are available and widely deployed – that is, they can take a person anywhere they want to go, at any time, in any weather – many of the barriers to adult mobility will be overcome (Eby, Molnar, & St. Louis, 2019). At the current time however, challenges remain in ensuring that CAVs are accessible, acceptable, affordable, and otherwise inclusive for older adults. Results from survey research (e.g., Hulse, Xie, & Galea, 2018; Schoettle & Sivak, 2015) suggest that while older adults recognize, perhaps more than drivers of other ages, the potential value of CAVs, they have mixed feelings about them in general, and these feelings are moderated by their trust and acceptance of the technologies as well as their experiences, with greater trust, acceptance, and experience associated with more positive feelings (Eby et al., 2019). Further, they appear to be more reluctant than drivers of other ages to willingly relinquish all vehicle control to technology. Thus, engineering and design professionals and others need to be sensitive to the concerns of older adults in designing and deploying CAVs to ensure that they are accessible, acceptable, affordable, and otherwise inclusive. There is a tremendous opportunity to build such sensitivity among students studying engineering, design, and other automotive-related fields, as an explicit part of their education.

This project built on and leveraged a previous grant from the University of Michigan (U-M) Diversity, Equity, and Inclusion (DEI) Office awarded to Dr. Lisa Molnar. The grant (entitled *Increasing Student Awareness of DEI Issues through Artistic Expression within the Context of Transportation and Mobility)* began with the premise that efforts to strengthen the principles of DEI in the education of students benefit from raising awareness and sensitivity around how these issues affect not only society in general, but more importantly, individual human users. The idea behind the grant was to use the context of transportation and mobility – especially how vulnerable populations such as older adults can maintain their mobility in the community and hence their quality of life and well-being – as a way to promote a more personal understanding among students of the importance of DEI. As part of the grant, design concepts, as well as explanatory text in the form of poetry and prose, created by students from the Stamps School of Art and Design were integrated into an exhibit that was displayed at the University of Michigan Transportation Research Institute (UMTRI) in the Patricia F. Waller Gallery (which celebrates the lasting legacy of Dr. Waller who served as UMTRI's director from 1989-1999 and had a strong and abiding interest in the human impact of transportation policy and practice).

2. PROJECT OBJECTIVE AND AIMS

2.1 Project Objective

The objective of this project was to increase students' awareness of and sensitivity to issues and needs of older adult accessibility, acceptability, affordability, and other aspects of inclusion related to CAVs, using a framework of experiential learning. "In its simplest form, experiential learning means learning from experience or learning by doing. Experiential education first immerses learners in an experience and then encourages reflection about the experience to develop new skills, new attitudes, or new ways of thinking" (Lewis & Williams, 1994, p. 5). The U-M College of Engineering (CoE) is deeply committed to experiential learning, as evidenced by its ongoing experiential learning initiative that involves the development and promotion of several core competencies such as creativity, empathy, teamwork, ethics, and global and cultural awareness. The stated goal of the initiative is to provide students with a framework to intentionally explore opportunities, engage meaningfully in experiences, reflect on what they have learned, and communicate the value of the core competencies they developed.

2.2 Project Aims

The project provided an opportunity for U-M students to be involved in all four aspects of experiential learning – exploring, engaging, reflecting, and communicating – as part of six primary aims intended to meet the project objective. The project aims were to:

1. Help students explore issues of older adult accessibility, acceptability, affordability, and other aspects of inclusion related to CAVs through presentations by members of the research team summarizing findings from a synthesis of the literature and community engagement with older adults themselves.

2. Provide an opportunity for students to directly engage with these issues through a class project implemented in the U-M Dearborn course HCDE 510, a graduate course on human centered design and engineering taught by Dr. Feng Zhou, an Assistant Professor in Industrial and Manufacturing Systems Engineering, College of Engineering and Computer Science at U-M Dearborn.

3. Encourage students to reflect on what they have learned from the class project, including how their potentially new thinking about older adults and CAVs fits within the university's experiential learning core competencies.

4. Provide an opportunity for students to communicate what they have learned through a poster session and reception held at UMTRI, with the posters remaining on display at UMTRI.

5. Evaluate the effectiveness of the proposed project through the administration of pre- and post-surveys to students intended to assess changes in students' knowledge and perceptions around the issues of accessibility, acceptability, affordability, and inclusivity of CAVs for older adults.

6. Develop recommendations for future efforts to train and educate students in this area, as well as for the design and deployment of CAVs themselves.

3. OVERVIEW OF TECHNICAL APPROACH

The project objective and aims were achieved through the completion of several primary tasks. These included: 1) completion of a research synthesis on older adults and CAVs by the project team; 2) discussions between the project team and older adults themselves (termed community engagement); 3) presentations by the project team to students in the class on the project background, findings from the research synthesis and community engagement, and an industry perspective on older adults and CAVs; 4) implementation of student classroom projects on older adults and CAVs as part of their regular course curriculum; 5) the development of posters by the students highlighting their classroom projects (including research questions, methods, findings, discussion); 6) presentation of the posters by the students in a formal poster session at UMTRI targeted to U-M faculty and staff, representatives from industry, and other undergraduate and graduate students; 7) evaluation through pre- and post-surveys of students to measure changes in knowledge about older adults and CAVs; and 8) development of a set of recommendations for future efforts to train and educate students in this area. Each of these tasks is discussed below, in terms of the methods used to accomplish the task and the findings that resulted from the task.

4. TASK 1: RESEARCH SYNTHESIS

The purpose of the research synthesis was to gather background information from the literature to gain a better understanding of the issues surrounding older adults and CAVs. In this section, we describe the methods used to conduct the research synthesis and the resulting findings.

4.1 Methods

The research synthesis was conducted through a scoping review of relevant published research literature, including journal articles, technical reports, and relevant websites, building on and extending work conducted by the project team (e.g., Eby et al., 2015, 2016, 2021; Molnar et al., 2015, 2018, 2021). The synthesis encompassed several activities including: 1) development of selection criteria to guide the review; 2) identification of topics to be included; 3) development of search terms to capture those topics; 4) collection and storage of relevant information in a bibliographic management system; and 5) multiple-level review of stored documents to identify appropriate documents for synthesis and integration of them into a written synthesis document. Given that vehicle automation is often defined using terms other than CAVs, including Automated Vehicles (AVs) and Automated Driving Systems (ADSs), we also used those terms to guide the research synthesis to ensure that we were capturing and describing the existing literature of interest to this project.

The research synthesis was guided by a set of selection criteria (e.g., type of document, time period for publication, geographic coverage). The criteria were intended to be reasonable, feasible to implement, and to yield a collection of documents that were comprehensive, manageable, and lead to meaningful results for this study. These selection criteria, highlighted below, were developed based on our knowledge of this field, recent reviews of the literature conducted by members of the project team (e.g., Eby et al., 2015, 2016, 2019; Molnar et al., 2015, 2018), and discussions among the project team. They were:

- Peer reviewed journal articles, technical reports, government reports, industry reports/documents, conference proceedings, and book chapters but no dissertations or full books were included.
- The documents above were supplemented with information from relevant websites.

- Literature providing at least some empirical evidence was included, but commentaries, editorials, opinion pieces, or letters to the editor without empirical evidence were not included.
- Literature from 2010 to the present was included as well as key/seminal literature from prior to 2010.
- Literature came primarily from US but also included countries or jurisdictions relevant to the traffic context in the US.
- Only literature written in English was included.
- Where appropriate, meta-analyses and systematic reviews were prioritized for inclusion rather than individual studies.

The review covered the following topics:

- Cognitive, psychomotor, and perceptual abilities that decline with age; overview and descriptions; prevalence in population.
- Automated Driving Systems (ADSs) and vehicle technology issues: how older adults understand, learn about, and use such technologies; barriers to use (e.g., accessibility, affordability, inclusion, acceptability); attitudes related to trust and acceptance.
- Design of ADSs and ADS deployment demonstration: inclusion of older adults in ADS design (e.g., human-centered design); challenges in deployment; successful strategies for deployment; overall lessons learned; ADS research involving older adults.

The research team identified starting sets of search terms that were used to search the literature for the identified topics. For each term listed, all permutations of the term were included in the search. For example, for the term “functional”, we searched function, functions, functioning, and so forth. We did this by entering the common stem for all of the expected permutations. Terms were combined into search strings (using AND, OR, etc.) to represent the myriad of ways the topics might be represented in the literature. The document search process was necessarily iterative; as appropriate articles were found, relevant subject and key word terms in those articles were used to refine the search and additional references were gathered.

Several document databases were searched: PubMed, PsycINFO, Transport Research International Documentation (TRID), ProQuest, ScienceDirect, and Google Scholar. Document gathering was facilitated by the University of Michigan’s MLibrary, which allows the University of Michigan employees electronic access to multiple literature databases and subscriptions to thousands of journals and other publications. All of the resources were organized using an online bibliographic tool called Zotero (https://www.zotero.org/) that allowed for all research team members to have access to the information. Documents and website information were reviewed by at least two members of the research team. Information deemed appropriate was included in the literature review and synthesized.

4.2 Findings

4.2.1 General Background

The ability of older adults to travel to places to which they need or want to go in their community and beyond (hereafter termed mobility) is essential to their everyday survival, as well as overall quality of life. In fact, mobility has been described as one of the cornerstones of healthy aging (University of Alabama at Birmingham, 2013). Mobility makes it possible for people to engage in activities such as commuting to and from work, accessing healthcare, shopping, and running other errands. Mobility also enables people to participate in activities that promote wellbeing and community engagement such as spending time with family and friends, being involved in recreational and social activities, attending religious services, and engaging in volunteer activities (Eby, Molnar, & St. Louis, 2019).

Driving oneself is the preferred means of mobility for older adults. This is due in part to the lack of alternative mobility options (Kostyniuk, Shope, & Molnar, 2000), and at least for the generation of baby boomers, to the 'driving culture' within which they grew up, as well as changes in family composition, the tendency to move out of urban areas, the increased affordability of automobiles, and the development of extensive roadway systems (McGuckin & Srinivasan, 2003). Unfortunately, evidence suggests that more than 600,000 older adults (age 70 or older) stop driving each year in the United States (US) and become dependent on others to meet their mobility needs (Foley, Heimovitz, Guralnik, & Brock, 2002). In addition, many people choose not to drive or are unable to drive themselves because of lack of access to a vehicle or insufficient financial resources to maintain a vehicle even if they have one. Numerous studies have shown that lack of mobility, often due to driving cessation but also for other reasons, can have a number of adverse consequences including loss of freedom and independence, reduced social participation and access to health care, decreased life satisfaction, increased depressive symptoms, greater likelihood of nursing home placement, and acceleration of more general health declines (e.g., Chihuri et al., 2016; Choi, Lohman, & Mezuk, 2014; Harrison & Ragland, 2003; Liddle et al., 2012; Marottoli et al., 1997; Rosso, Taylor, Tabb, & Michael, 2013).

CAVs hold great promise for helping older adults maintain mobility as they age. Taking into consideration the mobility needs and challenges of older adults in the design and deployment of CAVs and other automotive technologies has become increasingly important for at least three reasons. First, the populations of the United States (US) and many countries around the world are aging, a demographic shift that has occurred over the past several decades and one that is expected to continue (Eby et al., 2019). Second, as people age, they are more likely than other segments of the population to experience declines in perceptual, psychomotor, and cognitive abilities that are important not only for safe driving, but for maintaining mobility more generally (Charlton et al., 2010; Eby, Molnar, & Kartje, 2009). Third, although older adults represent one of the most heterogeneous segments of the population, as a group, their self-perceptions and aspirations with regard to their disabilities or impairments in functioning, and options for maintaining mobility can differ substantially from other segments of the population, especially the larger population of people with disabilities (Coughlin, 2005, 2007). Each of these three factors is explored more fully below.

4.2.2 Aging of the Population

In examining population trends around the world, Eby et al. (2019) found that the worldwide population is growing in number and becoming older. Looking toward the future, they noted that in most countries, there will be significantly more older adults, and they will account for a larger proportion of the total population than currently. In fact, by 2050, it has been estimated that the number of adults age 65 or over in the US will reach nearly 86 million, comprising over 20 percent of the population (US Census Bureau, 2018). That means that one in five people in the US will be age 65 or older (considered to be an older adult). This aging of the population has had a tremendous impact on all aspects of society, including transportation and mobility.

4.2.3 Declines in Perceptual, Psychomotor, and Cognitive Abilities

Many older adults experience declines in their perceptual, psychomotor, and/or cognitive abilities as a result of the aging process itself, as well as certain medical conditions that are more common in old age and the use of medications (prescription and nonprescription) intended to treat those conditions (Eby et al., 2019). Collectively, these functional declines can make it difficult for older adults to not only operate their own vehicle, but also to access and use other non-driving mobility options (e.g., walk to and from the vehicle, enter and exit the vehicle, arrange for rides; Bascom & Christensen, 2017; Bezyak, Sabella, & Gattis, 2017). In addition, these difficulties can be compounded when declines occur in multiple areas of functioning. For example, hearing loss has been shown to intensify the negative effects of visual or cognitive impairment (e.g., Green et al., 2013; McCoy et al., 2005). These interactive effects are important to take into account, given that as many as 80% of older adults have comorbid medical conditions (Buttorff, Ruder, & Bauman, 2017) that can lead to declines in more than one functional area. Age-related functional declines and the medical conditions that may give rise to them are explored more fully elsewhere (e.g., Charlton et al., 2010; Dobbs, 2005; Eby, Molnar, & Kartje, 2009; Owsley, 2011). A brief overview of the most common declines and associated medical conditions is provided here, based primarily on findings from a recent review by Eby et al. (2019).

<u>4.2.3.1 Perceptual abilities:</u> Perceptual abilities include both visual and hearing abilities. Several visual abilities have been shown to decline with age as a result of the normal aging process and the increased prevalence of various eye diseases (e.g., Anstey, Wood, Lord, & Walker, 2005; Attebo, Mitchell, & Smith, 1996; Ball & Sekuler, 1986; Hofstetter & Bertsch, 1976; Kline & Birren, 1975; Long & Crambert, 1989; Owsley, 2011; Owsley & Sloane, 1990; Schieber, Kline, Kline, & Fozard, 1992). Among these are: static and dynamic visual acuity (the ability to resolve details when objects are in motion and when they are stationary); glare recovery; contrast sensitivity (the ability to see in low light conditions); useful field of view (the area that can be seen without moving the eyes or head), and visual processing speed (the time needed to accurately judge what is being observed). There is also evidence that stereoscopic space perception (depth perception using both eyes) and motion sensitivity (symptoms caused or made worse by motion) decline with age, although these studies are less conclusive (e.g., Ball & Sekuler, 1986; Bell, Wolf, & Bernholz, 1972; Hofstetter & Bertsch, 1976; Jani, 1966; Schieber, Hiris, White, Williams, & Brannan, 1990). Among the leading causes of vision loss and/or blindness among older adults are cataracts (a progressive clouding of the eye's lens to the point of affecting vision; National Eye Institute, NEI, 2020a); retinopathy (a change in blood vessels of the retina that damage or obscure the retinal cells that overwhelmingly results from diabetes; NEI, 2020b); glaucoma (a buildup of fluid and pressure in the eye that damages the optic nerve leading to vision loss and blindness; NEI, 2020c); and age-related macular degeneration (gradual deterioration of the macula, a part of the retina responsible for sharp, detailed vision; NEI, 2020d). Vision impairment can also result from a color vision deficit (the inability to discriminate perceptually among different wavelengths of light, most commonly between blue-

yellow and red-green; Eby et al., 2009). An important but sometimes overlooked aspect of perception is hearing. Many older adults experience a gradual loss of hearing ability as they age (referred to as age-related hearing loss or presbycusis) due to changes that can occur in the inner ear (National Institutes of Health, NIH, 2016).

4.2.3.2 Psychomotor abilities: Individuals' psychomotor functioning refers to their ability to coordinate, control, and orient parts of their body (Kelso, 1982). A number of psychomotor abilities have been found to decline with age (e.g., Adams, O'Shea, & O'Shea, 1999; Der & Deary, 2006; Karthaus & Falkenstein, 2016; Klavora & Heslegrave, 2002; Reed, Liu, & Kalu, 2018). Among the most common of these are: reaction time; flexibility (the range through which a joint or muscle can move); coordination of movement; and muscle strength (with decreases in strength of up to 25% for older adults). In addition to the normal aging process, declines in psychomotor abilities can result from several medical conditions including arthritis, Parkinson's disease, multiple sclerosis, and paralysis (Eby et al., 2019; Falkenstein et al., 2020), as well as lack of exercise, or a decrease in overall activity levels (States, 1985). Paralysis may result from a stroke, or cerebrovascular event, which occurs when there is a clot, a rupture of a vessel, or a change in blood viscosity, causing loss of blood flow and cell death to a certain part of the brain. Other potential effects of stroke include difficulty speaking or understanding speech, vision problems, weakness, and balance problems (National Institute of Neurological Disorders and Stroke, NINDS, 2021).

4.2.3.3 Cognitive abilities: Cognitive abilities have to do with aspects of mental functioning (e.g., attention, formulation of knowledge, memory, judgement, evaluation, reasoning, problem solving, and decision making). Several cognitive abilities have been shown to decline with age, despite considerable individual differences among older adults (e.g., Eby et al., 2009; Drag & Bieliauskas, 2010; Harada, Love, & Triebel, 2013; Mather, 2010). These include: sustained attention (the ability to attend to relevant information for some period of time); selective attention (the ability to keep one's mind on important information while ignoring irrelevant information); divided attention (the ability to attend to multiple tasks at the same time); information processing speed; spatial cognition (one's ability to perceive and process the location and movement of objects in space); and executive functioning (related to one's ability to self-regulate goal-directed behavior and effectively organize and use large quantities of information).

In addition to the normal aging process, declines in cognitive abilities can result from several medical conditions including Alzheimer's disease and other dementias, mild cognitive impairment (MCI), and Parkinson's disease (Eby et al., 2019; Falkenstein, Karthaus, & Brüne-Cohrs, 2020). Dementia is a progressive disease, which is most commonly caused by Alzheimer's Disease (50%-75% of dementia cases) but can also result from vascular dementia (17%-30%), Lewy bodies (10%-15%), and fronto-temporal disorders such as Pick's disease (>5%; Alzheimer's Disease International, 2022). Symptoms of dementia include: a decline in cognitive skills such as memory, executive functioning, and reasoning; changes in personality; and wandering behavior (e.g., Alzheimer's Association, 2022; Eby et al., 2012). MCI represents a milder form of dementia in which individuals experience thinking and memory problems (e.g., losing items, forgetting appointments or events, difficulty recalling words or names) that are greater than expected for their age but do not disrupt their daily life (National Institute of Aging, 2022). Not all adults with MCI progress to dementia; findings from a retrospective study of 1,188 older adults with MCI indicated that about 32% progressed to dementia within an average of 2 years from MCI diagnosis (Glynn et al., 2021).

4.2.3.4 Prevalence of impairments: One consolidated source for estimating prevalence of impairments (or disabilities) in perceptual, psychomotor, and cognitive functioning among older adults and the larger population is the US Census Bureau's American Community Survey (ACS; US Census Bureau, 2021). Respondents are asked if they are experiencing difficulties in hearing, vision, cognition (remembering, concentrating, or making decisions), ambulation (walking or climbing stairs), self-care (bathing or dressing), and/or independent living (doing errands alone such as visiting the doctor's office or shopping). People who respond in the affirmative are considered to have a disability. Erickson, Lee, and von Schrade (2022) analyzed data from the 2019 ACS and found that disability increased with age. Across all ages, 12.7% reported having a disability; by age group, prevalence was: 0.7% for age 4 and under; 5.5% for age 5-15, 6.5% for age 16-20; 10.5% for age 21-64; 24.2% for age 65-74; and 47.1% for age 75 or older. These same investigators reported prevalence by disability type for each group. Results are reported in Table 4.1 for people of all ages and older adults age 65-74 and 75 or older.

Table 4.1: 2019 Prevalence of Disability by Type of Disability and Age

Disability	Age		
	All	65-74	75+
Any Disability	12.7	24.2	47.1
Visual	2.3	4.1	8.8
Hearing	3.6	8.6	21.1
Ambulatory	6.8	14.8	30.9
Cognitive	5.2	5.1	12.7
Self-Care	2.6	4.2	12.3
Independent Living	5.7	7.4	23.0

Source: Erickson et al. (2022).

Data from the ACS make it clear that prevalence of impairment/disability is higher among older adults than other age groups, particularly after the age of 75. At the same time, it is important to recognize that the older adult population is arguably more heterogeneous than any other segment of the population (Eby et al., 2019). In this regard, there is considerable variation in the extent to which older adults experience declines in perceptual, psychomotor, and cognitive functioning and the effects of these declines on mobility (Eby et al.,1998; European Road Safety Observatory, 2006). This variation results from a wide array of factors including individual and household characteristics, as well as social networks, and the built environment.

4.2.4 Self-Perceptions and Aspirations Relative to Disability

Despite the heterogeneity among older adults, as a group, they also share some common self-perceptions that have implications for the design and deployment of CAVs and other vehicle technologies, especially from a marketing perspective. The most consistent shared self-perception identified by Eby and Molnar (2012) was that older adults tend to see themselves as younger than their chronological age, generally by about 10 years (e.g., Markides & Boldt, 1983;

Myers & Lumbers, 2008; Sudbury & Simcock, 2009). Based in part on this observation, Moschis (2003) recommended that: the older adult consumer market should be segmented based on life events and circumstances (which influence individual needs and lifestyles), rather than based on age; products should be developed with an intergenerational or universal appeal (i.e., products that can satisfy the needs of both younger and older consumers but are most beneficial to the older adult); and that products should be promoted in a way that reinforces the "youthful" self-concept many older adults hold rather than emphasizing their old-age status.
Eby and Molnar (2012) also reviewed a growing body of research on the effects of aging on consumer decision making resources and abilities. An important finding was that as people age, they may experience physiological changes that can affect how they interact with the consumer environment, not only in terms of the products that might benefit them, but also how these products are advertised and marketed (Yoon & Cole, 2008). Yoon, Cole, and Lee (2009) identified several adaptations that older adults experiencing declines in abilities make in their decision-making processes including: greater reliance on selective searching, use of decision aids, delegation of decisions, training, and heuristic processing (i.e., using prior knowledge to develop simple decision rules rather than systematically processing information). The authors called for a better understanding of these adaptations by marketers to not only optimize their market mix but also guide the development of intervention strategies. Finally, work by Coughlin (2005) focused on the extent to which the vehicle design and marketing process should be planned to appeal to older adults, while at the same time meet the needs of people with disabilities. He argued that older adults may have similar functional requirements as people with disabilities, but they do not see themselves as disabled or equate their age-related functional declines as disabilities. He concluded that it will therefore be increasingly important to go beyond an understanding of older adults' functional needs as drivers to understand how their current and future lifestyles can be best accommodated.

4.2.5 Automated Driving Systems

Technology continues to transform the transportation system, particularly the development of technologies that can assist in the driving task called Advanced Driver Assistance Systems (ADASs). The most advanced ADASs are being developed with the capability of being able to take over all operation of the vehicle under certain circumstances (United States Department of Transportation, USDOT, 2020). According to the National Highway Traffic Safety Administration (NHTSA, 2017) and the Society of Automotive Engineers, International (SAE, 2018), ADSs can be classified by six levels of automation: Level 0 (momentary driver assistance); Level 1 (driver assistance); Level 2 (additional assistance); Level 3 (conditional automation); Level 4 (high automation); and Level 5 (full automation).

Implementation of ADS technologies could provide several benefits as discussed by NHTSA (2022):

- *Safety*: ADSs are designed to assist the driver and/or take over the vehicle's operation, thereby reducing the potential for driver error, a significant cause of roadway crashes and related injuries.
- *Mobility/Equity*: Declines in ability that are associated with aging or disabilities can make it difficult to drive safely, leading to reduced mobility for many people. Many underserved communities do not have access or are unable to use many mobility options,

also leading to reduced mobility. ADSs have the potential to improve mobility options and improve equal access to these options for all user groups.

- *Economic and Societal*: To the extent that ADSs reduce crashes, these technologies can reduce the costs associated with these crashes. ADSs can also reduce the costs of vehicle ownership (e.g., fuel, insurance, registration). ADSs also have the potential to increase access to employment for people who do not drive or have difficulty using other transportation options.
- *Efficiency and Convenience*: ADSs can make travel more efficient by traveling optimal routes, avoiding congestion, and reducing incidents of non-recurrent congestion caused by traffic crashes, saving time on trips and making travel more convenient.
- *Environmental*: Finally, implementation of ADS technology is predicted to be beneficial to the environment by decreasing air pollution, reducing fuel consumption, significantly reducing the need for parking spaces and associated real estate, and increasing the use of shared vehicles.

Here, we focus on synthesizing what is known about willingness to use, attitudes, and thoughts about ADSs as well as examining preferences for training/learning among a potential user group mentioned by NHTSA (2022) - older adults.

<u>4.2.5.1 Framework for technology adoption among older adults:</u> Currently, personal vehicles with Level 2 automation are available to the public and only limited Level 3 and Level 4 vehicles are being tested on public roadways. Because of this, investigating use, attitudes, and methods for learning how to use ADSs can be challenging. How do researchers provide study participants with an understanding of ADS system functions and features that is realistic when examples of the technology are not available for use in actual traffic conditions? Researchers have used several methods including: written or verbal descriptions of ADSs and their function (e.g., Kadylak, Cotton, & Fennell, 2021); computer-based driving simulators programmed with ADS features (e.g., Hartwich et al., 2019); classroom mock-ups that employ role-playing (e.g., Gluck et al., 2020a, 2020b); and accessing low-speed vehicles used in Level 3 or Level 4 demonstrations in real traffic or on a closed course (e.g., Classen et al., 2021a; Hartwich et al., 2019).

Researchers have used a number of frameworks or models to help predict whether older adults will accept, trust, and ultimately use ADSs (e.g., Isbel, Mulhall, & Gibson, 2022; Kadylak, Cotten, & Fennell, 2021). Several models of technology acceptance and intention to use have been applied to older adults and ADSs. These include the Technology Acceptance Model (TAM; Davis, 1985, 1989), the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), and the Senior Technology Acceptance and Adoption Model (STAM; Renaud & van Biljon, 2008). The STAM model classifies technology adoption and use among older adults as having three phases (Bernard et al., 2013; Renaud & van Biljon, 2008). The first is the *objectification* phase where older adults form opinions about intentions to use an ADS based on what they hear on the news, from friends, and other outlets, as well as on how useful they think the technology might be for them. The next phase is called *incorporation*. During this phase, older adults begin to use an ADS, experimenting with the features, operation, and capabilities, leading to more concrete opinions of the technology's trustworthiness and usefulness to them. The final phase is *acceptance*. If the incorporation phase shows that the technology is useful, then older adults will use the ADS. According to the model, the first two phases are influenced by the ease of learning to use the technology, pointing to the importance of effective methods for teaching older adults about how ADS technologies are used and their limitations. Based on the STAM model, intention should be predicted by perceptions and attitudes toward ADSs, particularly after gaining some experience with ADS technologies.

4.2.5.2 Perceptions of ADS technologies among adults: Using a variety of methods, several studies have found that older adults report overall negative attitudes toward ADS technology and greater negative attitudes when compared to younger research participants (e.g., Diepold et al., 2017; Hassan et al., 2021; Kadylak & Cotton, 2020; Kadylak, Cotton, & Fennell, 2021; Lajunen & Sullman, 2021; Peng, Yawen, & Zhen, 2019; Rovira et al., 2019). For example, a study of older adults in four countries investigated attitudes about Level 2-5 ADS technologies using a 5-point scale with higher scores indicating more positive attitudes (Lajunen & Sullman, 2021). Averaged across all four countries, the study found that as the level of automation increased, reported attitudes became more negative; that is, as the technology is designed to takes over more of the driving task, the less-older adults thought the technology was safe, trustworthy, enjoyable to use, reliable, comfortable, easy to use, and attractive. Interestingly, the greatest decrease in positive attitudes occurred between Level 2 ADS technology which is available on current vehicles and Level 3 ADS technology which is not available to the public. Figure 4.1 shows the average attitude scores for three of the seven attitudes investigated.

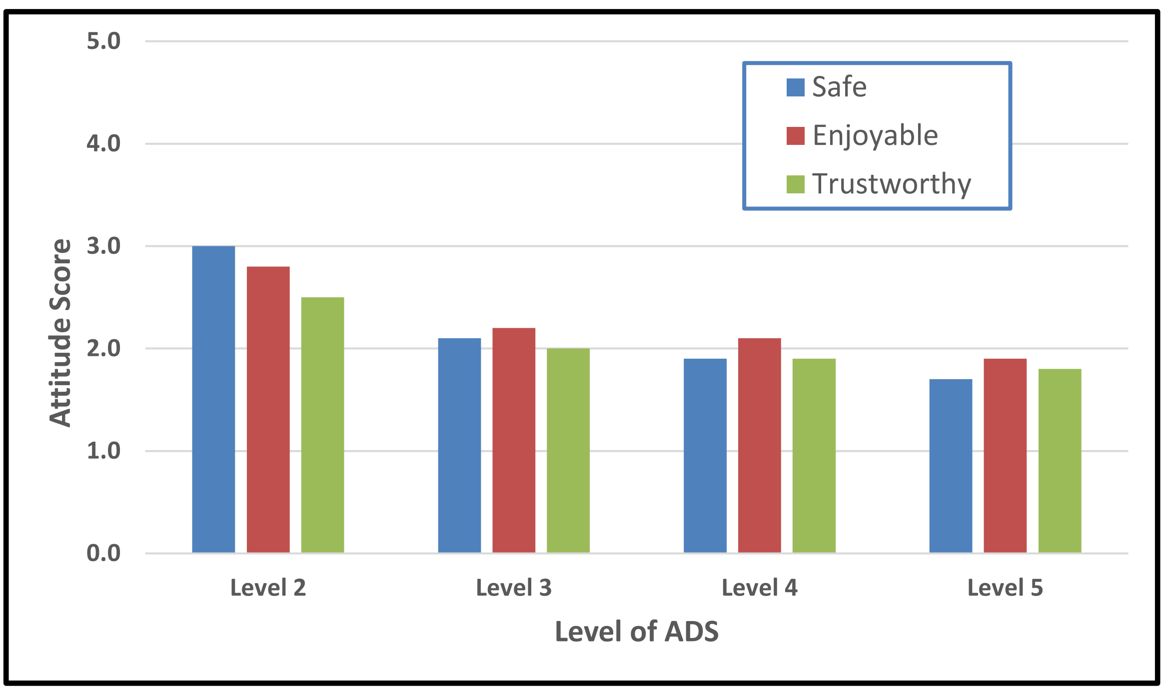

Figure 3.1: Selected Attitudes Toward ADSs among Older Adults by Level of Automation (Lajunen & Sullman, 2021)

A Canadian study that surveyed 1,000 older adults about their attitudes toward ADSs (termed fully automated vehicles, FAVs, which was equivalent to Level 5 ADS) also generally found negative attitudes (Hassan et al., 2021). Respondents reported their level of agreement with seven statements related to ADS technology. Figure 4.2 shows the percentage of older adults responding with either "Agree/Strongly agree", "Neutral", or "Disagree/Strongly Disagree". As seen in this figure, more than 40% of respondents disagreed or strongly disagreed that: they will use ADSs in the future; ADSs will be safer; ADSs will be their preferred mode of transportation; they would own an ADS; and they liked the idea of an ADS-based taxis service.

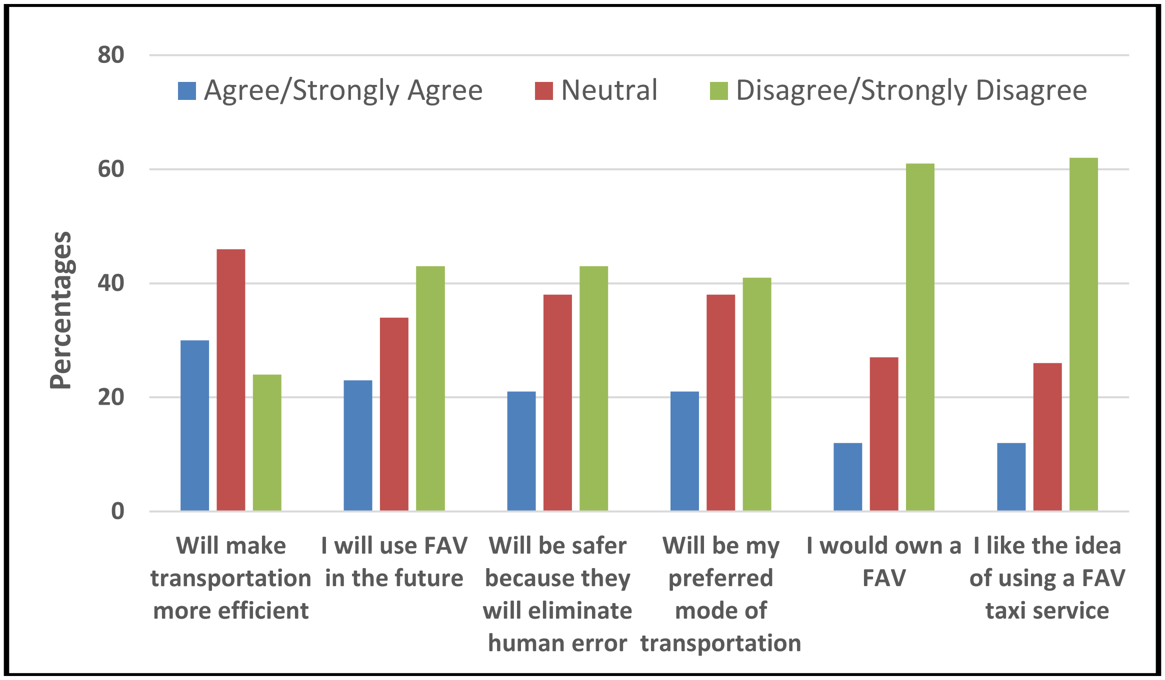

Figure 3.2: Percentages of Older Adults Agreement with Statements about ADSs (Hassan et al., 2021)

These relatively negative attitudes were likely related to the perceived concerns that these older adult respondents had about ADS technology. The study asked respondents to report their level of agreement with five statements of concern about Level 2-5 ADSs. Table 4.2 shows these results. Forty percent or more of respondents reported strongly agreeing or agreeing with each of the concerns investigated.

Table 4.2: Older Adults' Level of Agreement with Statements of Concern about ADSs

Statement	% Responding "Strongly Agree/Agree"
I would feel concerned about being legally responsible if a FAV [Level 5] technology failure causes an accident.	65%
I feel concerned about being legally responsible if SAV [semi-automated vehicle, Level 2-4] technology failure causes an accident.	63%
There has not been sufficient testing of SAVs [Level 2-4].	54%
I would not use FAVs [Level 5] in the future if they are more expensive than conventional vehicles.	48%
SAVs [Level 2-4] will not perform safely in all road and weather conditions.	40%

Source: Hassan et al. (2021).

4.2.5.3 Factors that moderate older adults' attitudes toward ADSs: Older adults' attitudes and opinions of ADS technology are not uniform. Several factors have been found in studies that moderate older adults' attitudes and opinions including: older men generally report more positive attitudes toward ADSs than older women (e.g., Hassan et al., 2019; Hohenberger, Spörrle, & Welpe, 2016; Hulse, Xie, & Galea, 2018); older adults with higher income and education levels generally report more positive attitudes toward ADS technologies (e.g., Hassan et al., 2019; Kadylak, Cotten, & Fennell, 2021); older adults who reside in urban areas generally have more positive attitudes toward ADSs (e.g., Hassan et al., 2019; Kadylak, Cotten, & Fennell, 2021); and older adults who report having functional declines that may make driving more difficult have more positive opinions than older adults who do not need help with transportation (e.g., Classen et al., 2021b; Kadylak, Cotton, & Fennell, 2021).

While studies clearly show that older adults are interested in the potential benefits of higher-level ADS technologies, their attitudes are linked to the specific features and functions of future ADSs (Gluck et al., 2020a, 2020b; Zandieh & Acheampong, 2021). Example features reported by older adults that have been associated with more positive attitudes included: ADSs providing door-to-door services (as opposed to, for example, waiting at a boarding location); the ability to include friends on trips; the ability to make changes during a trip or for the ADS to otherwise be flexible in its operations; the ability to change the seating arrangements to increase comfort and convenience; and to have some level of control over the ADS (e.g., Gluck et al., 2020a; Zandieh & Acheampong, 2021).

As discussed earlier, older adults' concerns about ADS technologies also moderate their attitudes toward this technology. Focus group and structured interview studies have identified several other concerns that older adults have with ADS technologies including: concerns about safely managing the transfer of control from the ADS operating the vehicle to the older adult having to operate the vehicle as would be the case in Level 2 and 3 ADS technologies; concerns about the technology being too expensive; concerns about a lack of effective training to learn how to use ADS technologies; concerns about the safety and reliability of the technology; and more general societal concerns such as declines in driving ability and etiquette and loss of social interactions

(Classen et al., 2021b; Faber & van Lierop, 2020; Gluck et al., 2020a; Huff et al., 2019; Li et al., 2019; Molnar et al., 2018; Siegfried et al., 2021; Zandieh & Acheampong, 2021).

As predicted by STAM, another important factor moderating older adults' attitudes toward ADS technologies is older adults' direct experience with the technologies (e.g., Lee et al., 2017; Molnar et al., 2018; Rahman et al., 2019). For example, a study that included 173 older adults from 39 US states asked respondents to rate their familiarity with Level 3 ADS technology and a 7-point scale anchored with labels 1 = "never heard of them" and 7 = "very familiar" (Rahman et al., 2019). The study found significantly higher ratings of positive attitudes, perceived usefulness, trust, perceived safety, and acceptance of Level 3 ADS technology with increasing familiarity with the technology. Other work provided older adult research participants with the opportunity to ride in a Level 4 ADS operating as part of a demonstration project (Classen et al., 2021a). The study found significant increases in older adults' reported perceptions of safety, trust, and usefulness after riding in the vehicle and experiencing how it functioned in real traffic conditions.

<u>4.2.5.4 Learning to use/training for ADS technologies:</u> All ADS technologies require or will require the user to know how to interact with the technologies as well as understand their operational limitations. Lower-level ADS technologies (Level 2-3) require the driver to maintain attention to the driving task and be ready to take over the control of the vehicle when necessary. For higher levels of automation (Levels 4-5), older adults will need to know how to request a ride, pay for it, board and exit, stow cargo such as mobility devices, and handle emergency situations, as well as address numerous other issues associated with using the technology. For all levels of ADS technology, the older adult will need to learn how the user interface works and how to communicate with the technology. Therefore, effective implementation of ADS technologies, particularly for older adults, will require careful consideration about how to teach people to use and understand them.

There is a lack of research investigating issues related to educating older adults about ADS technologies and this is, therefore, a fertile area for future research. Absent this specific information, there is an expanding body of research that has investigated how older adults learn to use ADAS technologies which include some of the features that are or will be incorporated into ADS technologies. Studies that have investigated how older adults learn to use ADAS technologies report that (AAA Foundation for Traffic Safety, 2008; Braitman et al., 2010; Eby et al., 2018, 2021; Eichelberger & McCartt, 2014): many older adults never learned how to use the technology and many do not use the technologies in their vehicles; older adults report a variety of methods and sources of information that they use to learn about ADAS technologies; large percentages of older adults teach themselves about the technology through trial-and-error; the dealer and the owner's manual are frequently cited sources of information about ADAS operation; and most do not access the Internet as their primary way to learn about ADAS technologies despite the abundance of Internet-based ADAS training information. For example, in a recent study of older adults in five US locations, investigators surveyed more than 2,374 older adults about how they learned to use 12 ADAS technologies installed in their personal vehicle (Eby et al., 2021). Table 4.3 shows the reported primary way respondents learned to use ADAS technologies combined across all 12 technologies.

Table 4.3: Primary Method Older Adults Learned to Use their ADAS Technologies Combined Across 12 Technologies

Primary Methods for Learning About ADAS Technology	% Reporting
Figured it out myself	51%
Dealer	21%
Never learned	11%
Owner's manual	10%
Family/friend	4%
Internet	<1%
Other	<1%
Previous experience	<1%

Source: Eby et al. (2021).

4.2.5.5 Conclusions: As the design and implementation of ADS technologies move forward, there is an evident need to address the concerns and expectations of older adults. Because perceptions and attitudes are strong predictors of whether or not older adults will embrace and use ADS technologies in the future, it is important to address these issues now and, in the future, when highly automated vehicles become a reality. It is clear that ADS technology professionals need to ensure that media about these technologies portray their features and functionality accurately so that the expectation of older adults can better match the realities of the technology. In the same vein, providing older adults with opportunities to experience ADS technologies first-hand will be an important component to their use and acceptance among older adults. Finally, as has always been the case for new automotive technologies that impact the driving task, there is a current and continuing need to develop training and education methods that are tailored to the way older adults learn and are accessible to older adults.

4.2.6 Automated driving system design and deployment

Great improvements in safe mobility could be made by designing vehicles that take into account declines in abilities commonly experienced by older adults (Eby & Molnar, 2012). To optimize the potential of ADSs to extend safe mobility of older adults, new technologies need to be adapted to the characteristics, preferences, and needs of this population, to be effective, efficient, and ultimately, well accepted (Bellet et al., 2018; Young, Koppel, & Charlton, 2017). Attitudes and perceptions about ADSs are influenced by many factors, including both the physical design and technological interfaces of the vehicle (Booth et al., 2022; Young et al., 2017). Although limited, researchers are beginning to explore ADS design centered on the preferences and needs of older adults, as well as people with disabilities (e.g., Padmanaban et al., 2021). This section provides an overview of issues in vehicle design, particularly with regard to ADS technologies, and the extent to which these issues are being addressed in current research and ADS deployment demonstrations.

4.2.6.1 Designing ADSs for Older Adults: For more than two decades, researchers have suggested that vehicle design features should be guided by knowledge of the effects of aging on crash outcomes (i.e., frailty and fragility) as well as an awareness of declines in psychomotor, visual, and cognitive abilities commonly experienced by older adults (e.g., Caird, 2004; Eby & Molnar, 2012; Herriotts, 2005; Pike, 2004). This includes the physical design features of the interior and exterior of a vehicle as well as design of in-vehicle information systems and advanced driver assistance system technologies. While design categories such as getting in and out of the vehicle, seating, and visibility of the external driving environment remain critical factors in vehicle design, the rapidly evolving area of advanced technologies offers an opportunity to ensure older adults are represented in the research and development phases of future ADSs.

Currently, the design of advanced technologies is largely informed by automotive Human Machine Interface (HMI) guidelines, and testing protocols are primarily centered on effectiveness for the 50th percentile young adult user (Campbell et al., 2016; Young et al., 2017). Older age groups present challenges to vehicle design due to wide-ranging physical and cognitive capabilities as well as differing attitudes towards technology. Researchers suggest that the fit between capabilities of the user and demands of the technology can be optimized using human-centered design, which is a multi-stage design process greatly focused on human factors engineering, usability engineering and user experience optimization (Harte et al., 2014). This approach to design begins with gaining a thorough understanding of the perspectives and needs of the group that will be using the product or innovation. In the context of older adults and ADSs, this would involve delving deeply into the previously discussed factors that moderate attitudes and perceptions about ADSs, as well as understanding how older adults learn to use such technology. The information would then be used to generate ADS design ideas and create prototypes that would then undergo iterative testing (IDEO.org, 2015). As needs of the end user are paramount in this paradigm, inclusion of older adults throughout the design process of ADSs could lend itself to more accessible vehicles, generate trust and acceptance of the technology, and inspire greater adoption of future ADSs.

Common characteristics of older adults, such as declines due to the normal aging process, have led to the rise of recommendations to engage in the human-centered design process with this particular age group. However, human-centered design in transportation and mobility planning is not commonly implemented, and even more rarely includes older adults. Young, Koppel and Charlton (2017) conducted a systematic review of automotive design guidelines for in-vehicle information systems and advanced driver assistance systems published or updated from 2000 to 2015. The review focused specifically on design information related to older adults. The review revealed that in-vehicle technology guidelines do not adequately account for physical and cognitive limitations of older drivers (Young et al., 2017). Indeed, most guidelines do not mention driver age, or sensory, cognitive, or physical impairments. When they are mentioned, statements are broad and do not provide explicit guidance on how vehicle design can accommodate limitations or declines in safe driving abilities that older adults often experience. Thoughtful and direct guidance is likely to have the added benefit of assisting a range of driver groups in addition to older drivers, such as novice drivers and drivers with disabilities (Young et al., 2017). This concept is termed universal design – that is, the process of creating products to be usable for all people, to the extent possible, without the need for adaptation (Connell et al., 1997).

<u>4.2.6.2 Three lenses of Human-Centered Design:</u> While there are many benefits to including aging adults in the design of vehicles and advanced technologies, there are practical constraints on designing products, such as ADSs, that have implications for the end users and the business developing the innovation. There must be a balance of desirability, feasibility, and viability for a

product or technology to be successful and sustainable. These three elements are termed the three lenses of human-centered design (IDEO.org, 2015). Figure 4.3 shows how each element overlaps. The product must meet the wants and needs of the end users (desirability), be technologically possible to create (feasibility), and the product must be profitable for the business (viability). Deficiencies in one area can result in less likelihood of a successful product. Therefore, ADSs designed specifically for aging adults may be both highly desirable for this population and technologically feasible, but may not be viable for a company to produce these vehicles due to high cost or lack of engagement from other user groups.

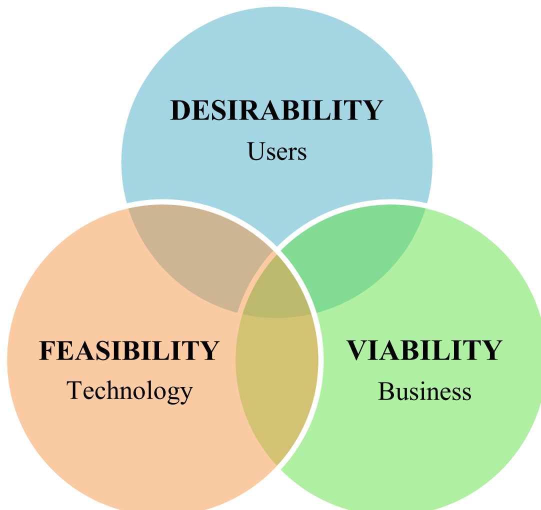

Figure 3.3: The three lenses of human-centered design

<u>4.2.6.3 Deployment Demonstrations:</u> ADS deployments have been implemented in numerous cities across the US and abroad. For example, a recent survey of 34 State DOTs and cities across the US found that 84% reported at least one recent or current ADS being tested or deployed in their region (CTSO Cooperative Automated Transportation & CAT Coalition Infrastructure-Industry Working Groups, 2020). Given the overwhelming number of demonstration deployments across the US, brief summaries of recent and current Michigan-based demonstration projects are found in Table 4.4. These deployments consisted of both passenger vehicles and low speed shuttles, were focused on a wide range of target users, had both on-demand and fixed-route services, and had different levels of accessibility for people with mobility impairments. Of note, one of the projects was focused on older adults (DMC Self-driving Shuttle Service). Specifically, this demonstration project operated a Level 4 autonomous shuttle on a fixed-route to provide transportation to older adults from two retirement communities to a large urban hospital.

Table 4.4: Current and Recent Michigan-based ADS Deployment Demonstrations.

Name	Target User	Summary	Reference/Link
A2GO	All riders	Downtown Ann Arbor. On-demand shared free rides to set pickup and drop off locations in a 2.64 sq mile service area accessed through a May Mobility app. Uses a fleet of vehicles, including one wheel-chair accessible vehicle. Project started October 2021 and is ongoing.	https://maymobility.com/deployments/
Autonomous Vehicle Grand Rapids (AVGR)	All riders, especially people with mobility disability	Downtown Grand Rapids, MI. Demonstration took place from July 2019 to April 2022. Free on-demand service accessed through a May Mobility app in 4.21 sq mile area. Four vehicles, one was wheel-chair accessible.	https://maymobility.com/deployments/
DMC Self-Driving Shuttle Service	Residents of two specified retirement communities	Demonstration project in Downtown Detroit to connect residents of two retirement community to the Detroit Medical Center Heart Hospital between August and October 2020. The project operated a Navya Autonom® Shuttle on a fixed 1.31 mile route during specified hours.	https://www.prnewswire.com/news-releases/self-driving-shuttle-service-launched-to-transport-senior-citizens-and-underserved-to-detroit-hospital-301114838.html
Mcity Driverless Shuttle	U-M faculty, staff, and students	Operated on the University of Michigan campus, Ann Arbor, from June, 2018 to December, 2020. Fixed-route, low speed, Level 4 Navya shuttle.	Kolodge, Cicotte, & Peng, 2020

Based on the number and variety of recent and current ADS demonstration projects, it is clear that there is a lot of enthusiasm toward the development of these systems and their future potential. However, there is a lack of formal evaluation of the demonstration projects that include both process evaluation and evaluation of user-centered outcomes. The literature review revealed one formal synthesis and comparison which focused on six deployment projects in the US. The three areas of information captured were location of the deployment, characteristics of the service, and the type of stakeholders involved (Haque & Brakewood, 2020). The study reported the following similarities across all demonstration projects: they were located in populated metropolitan areas; the frequency of stops was responsive to the demands of the riders and destinations; use of the service was free, each service had an on-board staff member for safety; the routes were short (i.e., between 0.5 to 2.5 miles); and all shuttles were low speed (i.e., maximum speed between 10-15 mph) with a capacity of 6-12 passengers. Additionally, the study reported that four stakeholder groups worked in partnership in each demonstration project: public organizations, partner organizations, shuttle manufacturers, and private operators (Haque & Brakewood, 2020).

A review of the literature also found one report that synthesized information about challenges of deployment demonstrations. Respondents from jurisdictions across the US that have recent or ongoing testing or deployments of ADSs identified several factors critical for the success of the demonstration project, and well as lessons learned from their involvement in the demonstration projects (CTSO & CAT, 2020). The type of information provided by the respondents closely aligns with the previously discussed lenses of human-centered design: desirability, feasibility, and viability. Factors for success included: safety; coordination, collaboration, and partnership; public engagement and acceptance; and the need to test new technologies to improve them. Lessons learned included: the importance of high public acceptance and enthusiasm for the deployment; the need to involve emergency responders as partners; the importance of maintaining a good relationship between the agency in charge of the deployment and vendor supplying the ADS; the need for the ADS technology to be reliable; and the importance of carefully considering the costs.

<u>4.2.6.4 ADS Research Involving Older Adults:</u> Given the abundance of ADSs currently deployed across the US, and the knowledge that familiarity and experience with ADSs contributes to attitudes, perceptions, and acceptance of these technologies (Classen et al., 2021a; Hassan et al., 2021), there has been an increase in research with methodologies that include providing participants with actual experience with ADSs of varying levels and different vehicle types, such as passenger vehicles and shuttles (e.g., Booth et al., 2022; Classen et al., 2021a; Isbel et al., 2022). The inclusion of older adults in research involving actual use of ADSs can help to provide additional insights to inform the development and implementation of future ADSs that are more accessible, acceptable, and useful for the aging population.

Findings from research conducted with older adults suggest that issues with accessibility and the physical layout of future ADSs are of major concern (e.g., Booth et al., 2022; Li et al., 2019). A recent study provided 30 older adults living in a retirement community with real experience riding in an automated shuttle. Following a 0.75 mile ride that lasted approximately 10 minutes, structured interviews were conducted where benefits and concerns of future utilization of automated shuttles were discussed (Booth et al., 2022). Participants reported several issues regarding the physical layout of the shuttle, such as narrow seats and limited space for personal items and mobility aids. While most of the participants were able to board the shuttle without assistance, the height of the step into the shuttle as well as the lack of an easily deployable ramp made accessing the shuttle difficult for those with mobility aids such as canes and walkers. One participant commented, “That really is going to be a huge problem – that actual step. I didn't realize it was so high” (Booth et al., 2022, p. 104).

The physical layout of the in-vehicle controls is also an important consideration for older adults. Isbel, Mulhall, and Gibson (2022) examined older adults’ perceptions about the usefulness of an ADS following a 3.6 mile ride in a Tesla Model S75, which is a Level 2 ADS. While most participants reported positive aspects about the experience riding in a partially autonomous vehicle, there were concerns about the location of the controls for the automated functions as well as the visibility of dashboard indicators. Participants commented that the stalk control was out of their sightline and required looking downward and away from the road to locate and operate the device. The authors suggested improved location of the automated function stalk as well as enhanced clarity of the associated dashboard indicators to optimize ease of use for older drivers.

In addition to the physical layout and design of ADSs, consideration for the type of route and the location where passengers can access the ADSs is important to older adults. Following a ride in a shuttle, participants in the Booth et al. (2022) study expressed concerns and provided recommendations regarding the accessibility of the shuttle's operating route. For instance, participants reported that for the shuttle to be used by people with mobility impairments, door-to-door service is necessary as getting to the shuttle at a fixed-route stop may be challenging. However, if shuttles were to operate on fixed-routes with designated stops, participants recommended the use of shelters to protect passengers from exposure to the elements and provide seating while waiting for the ADS to arrive (Booth et al., 2022). As noted previously, the prevalence of impairment and disability is higher among older adults than other age groups, and this has critical design implications for future ADSs and their deployment. In fact, ADS testing and deployment timelines and legislation often fail to mention accessibility for people with disabilities (National Council on Disability, 2015). Feedback provided by participants in studies such as those mentioned give weight to the importance of the inclusion of older adults in the design and prototyping processes of ADSs to create more accessible and acceptable vehicles.

<u>4.2.6.5 Conclusions:</u> The design of ADSs has the ability to influence user acceptance, trust, and accessibility for older adults. As the design and implementation of ADS technologies continue to advance, it is critical that future work establishes how older driver capabilities and limitations can be supported with the vehicle design process, including taking full account of this population in HMI guidelines. Research that explores accessibility and experiential needs of older adults as well as people with disabilities will become increasingly important as higher levels of automated technology become available (Brinkley et al., 2019). Vehicle design engineers, as well as students who aspire to work in similar industries, would benefit from employing approaches to design that include the aging population as full participants in the design and deployment processes.

5. TASK 2: COMMUNITY ENGAGEMENT

The purpose of the community engagement component of the study was to learn more about potential benefits and barriers to using CAVs by talking with older adults themselves. The knowledge obtained from the community engagement component was shared with the students as part of the classroom project to increase their awareness of and sensitivity to issues surrounding older adults' CAV use. In this section, we describe the methods used to conduct the community engagement and the resulting findings.

5.1 Methods

Older drivers' perceptions of potential benefits of and barriers to using CAVs were explored using two qualitative approaches in sequence: nominal groups and focus groups. We previously used this two-phased qualitative approach to explore facilitators and barriers in access to Graduated Driver Licensing programs (Zakrajsek et al., 2010). The purpose of the nominal groups was to provide a structured means of identifying benefits and barriers that older drivers perceive and/or experience related to using CAVs. The nominal group Technique has shown particular promise as an accessible group research method for people with varying needs (Olsen, 2019). The purpose of the focus groups was to explore the benefits and barriers identified during the nominal groups in more depth and identify potential enhancements or solutions to them through a facilitated group discussion. Detailed descriptions of the nominal group and focus group procedures are provided below.

Twenty older drivers participated in the two-phased qualitative process (Figure 5.1). Ten participants were assigned to discuss benefits of using CAVs. Those participants participated in one nominal group session about CAV benefits, followed by one focus group session about CAV benefits one week later. Similarly, ten participants were assigned to discuss barriers to use of CAVs. Those participants participated in one nominal group session about CAV barriers, followed by one focus group session about CAV barriers one week later. The benefits and barriers were addressed by separate participant groups so that the discussion of barriers was not influenced by a prior discussion of benefits, or vice versa.

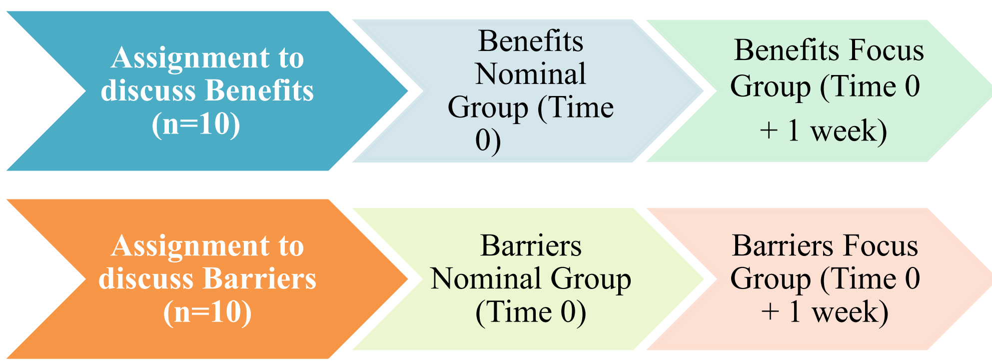

Figure 4.1: Two-Phased Qualitative Process

The nominal and focus group sessions were approximately 90 minutes each with one break and refreshments. At the beginning of each session, the moderator described the purpose of that session, pertinent background information about the topic, the ground rules to ensure equitable opportunity for all participants to contribute to the discussion, and the session agenda. During the introduction, participants were shown a short video defining CAVs and were asked to think about vehicles with Level 3-5 automation during the discussions. Participants' questions about the nominal/focus group process were answered before beginning each discussion. Each session was attended by a note-taker who recorded field notes about group interactions, body language and non-verbal cues expressed by participants. Participants received an incentive payment of $40 for participating in the nominal group, and to provide added incentive to return, they received $60 for participating in the subsequent focus group.

All sessions were conducted in-person at UMTRI. The same conference room (seating capacity of 34) was used for each session. Light refreshments were provided to the participants. Each session was facilitated by a trained moderator, with experience moderating over 20 nominal groups and over 90 focus groups previously. All planned procedures and supporting documents for the Community Engagement component were reviewed by the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board and were determined to be exempt from oversight.

5.1.1 Participants

Participants were recruited via a posting on umhealthresearch.org. Eligible participants met the following criteria: 1) Age 65 and older and 2) able to attend two group sessions at UMTRI. Prospective participants were screened for eligibility via telephone and passed a six-item screening instrument to ensure that they were not cognitively impaired. Group assignment was balanced by sex then randomized. Some adjustments were made to group assignment to accommodate participants' schedule availability, however the groups remained balanced by sex.

Participants' current medical conditions were recorded from their umhealthresearch.org profiles but specific conditions were not targeted or factored into the group assignment. Participant characteristics are presented in Table 5.1 below. Ages ranged from 65-76 with a mean of 70.

Table 5.1: Participant Characteristics

Sex	Age	Has Driver's License	Current Medical Conditions
CAV Benefits Group			
M	75	Yes	Hypertension, High Cholesterol
M	67	Yes	None
M	69	Yes	None
M	74	Yes	Glaucoma
M	72	Yes	None
F	67	Yes	Migraine, Hypertension, Osteoporosis
F	67	Yes	High Cholesterol, Positional Vertigo
F	76	Yes	Obesity, Spinal Stenosis, Chronic Back Pain
F	74	Yes	Atrial Fibrillation, Gastroesophageal Reflux Disease, High Cholesterol, Osteopenia
F	72	Yes	Hypertension, Environmental Allergies
CAV Barriers Group			
M	69	Yes	Hypertension, Hyperglycemia
M	71	Yes	Apnea, Hyperglycemia, Cancer, Gastroesophageal Reflux Disease, Chronic Back Pain, Chronic Obstructive Pulmonary Disease
M	67	Yes	Schizophrenia
M	71	Yes	Apnea, Diverticulitis, Hypertension, Gastroesophageal Reflux Disease, Astigmatism, Coronary Artery Disease
M	65	Yes	Glaucoma
F	69	Yes	High Cholesterol, Kidney Disease, Hypothyroidism, Anxiety Disorder
F	69	Yes	Asthma
F	67	Yes	Macular Degeneration, Osteoarthritis
F	67	Yes	Tinnitus, Insomia
F	68	Yes	None

5.1.2 Nominal Group Procedures

The protocol for both nominal groups consisted of six steps focused on a single question per group. The question for the barrier-group was, *"How could using CAVs be difficult or challenging for older adults?"* Similarly, the question for the benefits-group was, *"How could using CAVs help older adults?"*

1. Participants were asked to, independently, create a list containing as many responses to the question as they could think of.
2. Participants presented their ideas using a round-robin approach. The moderator rotated through the group and asked each participant to share one item from his/her list. The moderator wrote each item on a whiteboard. This process continued until each participant had shared all of the items on his/her list.
3. The moderator asked for clarification of each item on the list to ensure that the items were correctly and similarly understood by all participants. Items were combined as determined appropriate by the group based on this discussion. This was repeated for each item on the list.
4. Each participant selected their top five most salient barriers/benefits and rank-ordered them.
5. When discussion resumed after the break, the moderator revealed the scores, eliminated items that had received zero votes, and conducted a second round of clarification for the scored items following the same procedures described in step 3.
6. Participants were given five new index cards and a final vote was taken following the same procedures described in step 4. After the participants departed, the scores were tallied and the top five items were identified. Those results were not shared with the participants until the focus group.

5.1.3 Focus Group Procedures
One week after the nominal group, the same participants reconvened to participate in a focus group discussion of the five items that received the highest scores during the nominal group. The moderator revealed the top five items and led a discussion of those items designed to further define and describe each of the top-rated benefits/barriers and identify potential solutions to the barriers or ways to augment the benefits. Both focus group discussions were audio-recorded to augment the notetaker's field notes. Participants were given paper and encouraged to write down any comments they had wanted to share with the moderator but were not able to share due to time constraints or did not feel comfortable sharing during the discussion.

5.1.4 Data Management and Analysis
Data from the nominal group lists, digital recordings of the focus group interviews and accompanying field notes were transcribed and entered into coding tables for data management. The transcribed interviews were analyzed using an open, focused coding process (Strauss& Corbin, 1998). Codes (i.e., summary terms using the words of the respondent) were assigned through a line-by-line, cross-interview analysis of the raw data. From the codes, focused code categories that exemplify specific themes that emerged from the data were developed. Using a method of constant comparison (Strauss & Corbin, 1998), these coding categories and themes were revised and refined based on an examination of internal and external homogeneity (Patton, 2001). Several key concepts were used to weight the data where appropriate throughout the analytic process: frequency, extensiveness, intensity, specificity, consistency, and participants' perceptions of importance (Krueger & Casey, 2014). For example, how often was an opinion repeated (frequency) versus how many different people stated an opinion (extensiveness) versus how much passion was behind the opinion (intensity) versus how much detail was provided about an opinion (specificity) versus how consistent participants were in their opinions (consistency) versus the extent participants said an opinion was important (perceived importance).

5.2 Findings
5.2.1 CAV Benefits
5.2.1.1 Nominal Group Results – CAV Benefits:
The top five benefits of using CAVs for older adults were:

1. Accident prevention (e.g., obstacle detection)
2. Feel safe despite physical limitations (e.g., vision, hearing)
3. Can drive any time (weather, day/night, etc.)
4. Autonomous driving helps with fuel efficiency
5. Lower anxiety level

The complete Round 2 voting results with scores listed are presented in Table 5.2 below.

Table 5.2: Round 2 Voting Results on CAV Benefits

	Item	Round 2 Votes	Round 2 Score
~~A~~	~~Obstacle detection for changing lanes~~	combined with L prior to Rd 1	
B	Improved response compared to humans	1+2+5	8
C	Feel safe despite physical limitations (e.g., vision, hearing)	5+1+4+4+5+5+5+4+4	37
D	Automatically decides best route	3+1	4
~~E~~	~~Traveling with friends and family more enjoyable~~	eliminated in Rd 1 voting	
F	Vehicle can drop off at door – avoid parking challenges	3+2+2	7
G	Frees to explore areas that might otherwise avoid (due to directions, parking, etc.)	1	1
H	Automatic braking helps with reflexes, vision, etc.	4+2	6
I	Autonomous driving helps with fuel efficiency	2+2+3+1+4+1+1	14
J	Less need for driver to know about or have to operate vehicle functions/mechanics		0
K	Can drive any time (weather, day/night, etc.)	3+1+2+4+3+4+3	20
L	Accident prevention (e.g., obstacle detection)	4+5+5+5+2+4+5+3+3+5	41
M	Lower medical costs	1	1
N	Lower insurance costs		0
O	Ability to share vehicles		0
~~P~~	~~Less need for public transportation~~	eliminated in Rd 1 voting	
Q	Lower anxiety level	3+3+1+2+2	11
~~R~~	~~Easier access to public transportation~~	eliminated in Rd 1 voting	

5.2.1.2 Focus Group Questions – CAV Benefits:

The following questions were used to frame the CAV benefits focus group discussion and were designed to obtain more detailed descriptions/examples of each benefit plus participants' perceptions of how benefits could be optimized via training for older adults and/or CAV design. Each benefit was discussed for approximately 11 minutes.

1) Accident prevention (e.g., obstacle detection)
    a) In what ways can CAVs help prevent accidents?
        i) What are some examples of how this helps older adults?
    b) How can accident prevention associated with CAVs be optimized for older adults?
        i) Probe for CAV design.
        ii) Probe for CAV training.
2) Feel safe despite physical limitations (e.g., vision, hearing)
    a) What are some of the physical limitations that CAVS can impact?
    b) In what ways can CAVs make older adults feel safe despite physical limitation?
        i) Probe for each physical limitation mentioned in a)
    c) What are possible ways to increase or optimize how CAVs make older adults feel safe despite physical limitations?
        i) Probe for CAV design.
        ii) Prob for CAV training.
3) Can drive any time (weather, day/night, etc.)
    a) What are some situations that older adults might not drive in without CAVS, but could with CAVs?
    b) In what ways can CAVs help older adults drive in these situations?
        i) Probe for each condition mentioned in a)
    c) What are possible ways to increase or optimize how CAVs can help older adults travel in any situation?
        i) Probe for CAV design.
        ii) Probe for CAV training.
4) Autonomous driving helps with fuel efficiency
    a) What are some examples of how CAVs impact fuel efficiency?
    b) How can this affect older adults?
    c) What are possible ways to increase or optimize how CAVs' fuel efficiency can help older adults?
        i) Probe for CAV design.
        ii) Probe for CAV training.
5) Lower anxiety level
    a) What are some examples of how CAVs can lower anxiety?
    b) How can this affect older adults?
    c) What are possible ways to increase or optimize how lower anxiety related to CAVs can help older adults?
        i) Probe for CAV design.
        ii) Probe for CAV training.

5.2.1.3 Focus Group Results – CAV Benefits: A summarized narrative of the leading themes that emerged from the discussion of CAV benefits is presented below. Unless otherwise noted, the specific items listed under each leading theme were mentioned by a single participant.

1) Accident prevention (e.g., obstacle detection)

Ways CAVs prevent accidents

- CAVs will respond to sudden stops faster than older adults can (mentioned by two participants plus consensus nods)
- CAVs will be alerted to and adjust to road issues like traffic back-ups and potholes (mentioned by two participants)
- CAVs will detect smaller road users, like motorcycles, that older adults might not see quick enough
- Hopefully CAVs will prevent people from driving recklessly which has increased recently (mentioned by two participants plus consensus nods)
- Communication between vehicles will prevent accidents (mentioned by two people plus consensus nods)

Uncertainties related to accident prevention by CAVs

- What will happen during the transition period when there will be a mix of CAVs and non-CAVs on roads?
- Many older adults will be resistant to using CAVs due to lack of understanding about CAVs, fear that CAVs are not 100% reliable, and negative perceptions due to high profile Tesla crashes (mentioned by two participants plus consensus nods)

Ways to optimize how CAVs make older adults feel safe despite limitations

- Prove to older adults beyond doubt that CAVs are safe (consensus nods)
    - Videos and in-person action showing older adults using CAVs
    - Partner older adults with trusted mentors (like kids/grandkids) for training
    - Training/encouragement should not come from the government – there is too much mistrust
    - Training/encouragement should come from trusted sources like universities and/or NHTSA (mentioned by two participants)
- Include older adults and/or senior organizations in planning training/outreach
- Give older adults hands on experiences with CAVs (shuttles, rides, demos) hosted by universities

2) Feel safe despite physical limitations (e.g., vision, hearing)

Limitations impacted by CAVs

- Reaction time (consensus nods)
- Head and neck range of motion (consensus nods)
- Neurological conditions (e.g., Parkinson's, tremors, post-stroke)
- Memory issues – many older adults give up driving because they cannot remember how to get places (consensus nods)
- There are many reasons people give up driving

How CAVs impact limitations

- CAVs reduce the need for older adults to have good vision and/or hearing to continue to drive
- Cameras and sensors can really benefit those with vision impairments. Most older adult drivers have already experienced this with back-up cameras and expect CAVs to help even more.
- CAVs can improve older adults' ability to hear in vehicles (e.g., sirens, brakes, crashes) (mentioned by two participants plus consensus nods)
- Older adults with neurological disorders will be helped by CAVs navigating them to their destinations, but these individuals may need help programming the CAV.

Strategies to optimize how CAVs make older drivers feel safe despite limitations

- Pair people with disabilities (old and young) with CAV tutors (mentioned by two participants) that are trusted mentors
- Use videos and advertisements to promote the benefits of CAVS to older adults
- Promote CAVs to older adults through
    - Churches
    - Senior organizations
    - Rehabilitation centers and primary care providers
    - Insurance companies
    - Auto dealerships
- Provide subsidies to help people learn about and access CAVs
- Provide CAV training for free
- CAV features in vehicles should be designed with fonts, buttons, and displays that are big enough and clear enough for older adults to see and hear
- Training materials and the training content itself should also be accessible to all

3) Can drive any time (weather, day/night, etc.)

Situations that older adults might not drive in without a CAV, but could with a CAV

- Almost all weather conditions – except those where even a CAV could still get stuck
- Day, night, and anywhere in between (mentioned by two participants plus consensus nods)

Ways CAVs help older adults drive in situations where otherwise could not

- Drivers become passengers and are not drivers anymore (mentioned by three participants)
- One participant shared that they currently cannot reach senior center or doctor without driving self. CAV would allow him/her to go to those destinations in snow, rain, and dark which currently he/she avoids.

Challenges that CAVs do not solve

- People still need to get to their CAV and may not want to or be able to in bad weather and/or lighting
- Who will really be buying CAVs? Will personal or public CAVs and related benefits get to be a class thing?

Ways to optimize how CAVs can help older adults travel in any situation

- CAV interiors should be designed to be comfortable and accessible and give the greatest number of older adults the opportunity to use these vehicles
- Vehicle entry and exit needs to be designed to accommodate a variety of physical limitations and devices
- We need to have a variety of CAVs available to meet the needs and resources of a range of older adults – CAVs that are small, large, cheap, fancy, etcetera but they all need to have basic CAV safety features

4) Autonomous driving helps with fuel efficiency

Ways CAVs impact fuel efficiency

- Reduced hard stopping and starting (mentioned by two participants)
- More consistently controlled speed
- CAV will determine most efficient routes to destinations
- Vehicle design will be more fuel efficient than current vehicles and will likely utilize electric power (mentioned by two participants)
- Connected vehicles and intersections mean vehicles will not be idling at stop lights

Ways fuel efficiency affects older adults

- Many older adults are on fixed incomes and reduced fuel costs will help them financially
- Financial considerations could factor into routes older adults take but not as likely to impact if they take day-to-day trips, it could factor into vacation planning though (consensus nods)
- Many interconnected issues: older adults are on limited income and interested in anything that will save them money and there are potential benefits to society in general due to less gas consumption
- Maybe the combination of this and other CAV benefits can lead to reduced insurance rates

How can this be promoted to older adults as a benefit of CAVs?

- Include in marketing materials from auto companies
    - Another participant said he/she would not trust this claim from auto companies, and it would be better from consumer reports or other resources (consensus nods and laughter)
- AAA magazine
- NTSB or comparable agency in the DOT
- AARP (consensus nods)

5) Lower anxiety level

Ways CAVs could lower older adults' anxiety

- Have experience reduced anxiety from back-up camera and this would be even more of that (consensus nods)

- Look forward to the CAV handling heavy traffic, construction traffic, cars merging in a city, fast traffic, and nighttime driving

At this moment, the idea of CAVs may increase older adults' anxiety

- If you rely too heavily on technology, you will dull your senses
- Still hesitant about CAVs – not convinced it will be 100% reliable. Knowing the technology is coming regardless increases his/her anxiety.
- Beeping noises made by current advanced technology features increases anxiety and they expect it to be the same with CAVs (mentioned by two participants)

Ways the reduced anxiety from CAVs can be optimized

- The design needs to ensure that older adults have control over these features and can set them to avoid increasing anxiety and/or eliminate beeping (mentioned by three participants)
- Need universal design to make it simpler for older adults to use any CAV
- Design needs to accommodate hearing impaired drivers or be customizable to accommodate hearing impaired drivers
- As the cars get more complex, need more comprehensive training from CAV sellers (consensus nods)
- More than one training session will be needed to fully learn and feel comfortable with the technology
- Older adults need a safe place where they can test out CAVs (mentioned by two participants plus consensus nods)
- There is tension between having control and giving up control for safety (with travel, with COVID, etc.) and maybe CAVs can provide a good balance (mentioned by three participants)
- The technology may not perfect but probably will be safer

5.2.2 CAV Barriers

5.2.2.1 Nominal Group Results – CAV Barriers: The top five barriers were:

1. Learning how to use the technology
2. Makes vehicles more expensive
3. Reluctance to give up driving/controlling the car
4. Concern that technology is user-friendly enough to use independently
5. Intimidated by the technology

The complete results with scores listed are presented in Table 5.3.

Table 5.3: Round 2 Voting Results on CAV Barriers

	Item	Round 2 Votes	Round 2 Score
~~A~~	~~Loss of control~~	Combined with X prior to Rd 1	
B	Dependency on the technology		0
C	Makes vehicles more expensive	5+4+3+5+1+4	22
D	Learning how to use the technology	2+5+5+5+2+4+4+3	30
E	Entering and exiting the vehicle	1	1
F	Trusting that the systems won't fail		0
G	Concern that technology is user-friendly enough to use independently	3+4+4+1+1	13
~~H~~	~~Anxiety related to unexpected motions~~	eliminated in Rd 1	
~~I~~	~~Falling asleep~~	eliminated in Rd 1	
J	Technology vs free will	5	5
K	Ability to hear car's signals/communicate with car	3	3
~~L~~	~~Controls need to be visible and accessible~~	eliminated in Rd 1	
~~M~~	~~Ability to operate vehicle at night if visually impaired~~	eliminated in Rd 1	
N	How will the transition to cavs take place?	2+2+2	6
~~O~~	~~What are the benefits of CAVs for people who don't drive often?~~	eliminated in Rd 1	
P	Increased multi-tasking		0
Q	Intimidated by the technology	3+1+3+2+2	11
R	Learning curve needed to trust CAVs		0
S	Universal functions	4+4	8
T	How will CAVs help mobility for older adults?		0
U	Stubbornness		0
V	How will visually impaired locate CAVs?		0
W	Concerns about tracking (being tracked)	3	3
X	Reluctance to give up driving/controlling the car	2+2+5+3+5+5	22
Y	Fear of the unknown and change	1+1+1	3
Z	Will CAVs determine permission re where and/or when travel?		0
~~AA~~	~~Software update needs~~	eliminated in Rd 1	
AB	How get CAV to respond in medical emergency	1+4+3	8
~~AC~~	~~Endless energy needs to operate~~	eliminated in Rd 1	

5.2.2.2 Focus Group Questions – CAV Barriers: The following questions were used to frame the CAV barriers focus group discussion and were designed to obtain more detailed descriptions/examples of each barrier plus participants' perceptions of how barriers could be minimized via training for older adults and/or CAV design. Each barrier was discussed for approximately 11 minutes.

1) Learning how to use the technology
    a) What do older adults need to learn to use CAVs?
        i) What kinds of things do you think older adults might need to learn?
    b) How can older adults learn to use CAVs?
        i) Probe for each response in a)
    c) What are possible ways to improve how older adults learn to use CAVs?
        i) Probe for CAV design.
        ii) Probe for CAV training.
2) Makes vehicles more expensive
    a) In what ways might CAVs make vehicles more expensive?
    b) What are some examples of how this could impact older adults?
    c) What are possible ways to help older adults deal with CAV costs?
        i) How can CAV costs be minimized for older adults?
        ii) Probe for CAV design.
        iii) Probe for CAV training.
3) Reluctance to give up driving/controlling the car
    a) What are some examples of things drivers might have to give up with CAVs?
    b) In what ways can giving things up affect older drivers?
        i) Probe for each item mentioned in a)
    c) What are possible ways to help older drivers deal with giving up control with CAVs?
        i) Probe for CAV design.
        ii) Probe for CAV training.
4) Concern that the technology is user-friendly enough to use independently
    a) What are some examples of things older adults might need help with using CAVs?
        i) How often would older adults need help?
    b) If help is needed from others to use CAVs, how would that affect older adults?
    c) If help is needed, from whom or where would older adults likely get help from?
        i) Whom/where would older adults be comfortable getting help from?
        ii) Whom/where would be capable of helping adults?
    d) What could be done to help CAVs be user-friendly enough for older adults?
        i) What is 'user-friendly enough'?
        ii) Probe for CAV design.
        iii) Probe for CAV training
5) Intimidated by the technology
    a) What are some examples of things about CAV technology that could intimidate older adults?
    b) How can this affect older adults?
    c) What are possible ways to make CAV technology less intimidating for older adults?
        i) Probe for CAV design.
        ii) Probe for CAV training.

5.2.2.3 Focus Group Results – CAV Barriers: A summarized narrative of the leading themes that emerged from the discussion of CAV barriers is presented below. Unless otherwise noted, the specific items listed under each leading theme were mentioned by a single participant.

1) Learning how to use the technology

What older adults need to learn

- Where, what, and how to use controls/buttons
- What we don't need to worry about anymore,and what we do need to know
    - Participants assumed there will be things about driving/vehicles they will not have to worry about anymore as CAVs emerge. Similarly, they assume new (currently unknown) concerns will emerge
- Advances in the technology – what we think we know could change abruptly and how will older adults keep up with that?

Best ways to help older adults learn to use CAVs

- Targeted training for older adults
    - You are taking older adults from something they grew up with to something that's really foreign to them
- Hands on experiences with CAVs– see and do (mentioned by two participants plus consensus nods)
- Accommodate different learning styles and rates of learning (mentioned by two participants plus consensus nods)
- Have a person designated at the dealership as the go-to resource for people to go to for CAV help

How could vehicle design help older adults learn to use CAVs

- Vehicle voice commands to provide instruction (consensus nods)
- Interior lighting and displays to help people with low vision (mentioned by two participants)

Miscellaneous

- The transition period with the technology still developing and a mix of vehicles on the road will be the most challenging to help older adults learn to use CAVs
- Training is not needed forever - once everything is autonomous learning how to use the technology won't matter so much

2) Makes the vehicles more expensive

Ways CAVS will make vehicles more expensive

- Everything! (i.e., purchasing, using, maintaining, repairing, insuring, etc.)
- Initial purchase because of the CAV features and the technology in the vehicles (consensus nods)
- Repairs (to both the vehicles and the CAV technologies in them)
- Technology updates – these will be constantly changing systems

    - Monthly/annual subscriptions will be needed for technology updates (consensus nods)
- Taxes will increase to pay for infrastructure improvements needed for CAVs to operate

Impact of cost on older adults

- Mixed expectations regarding the extent of the impact of cost on older adults
    - For some increased costs associated with CAVs was a concern due to many older adults having fixed incomes
    - There would be only a small impact of cost on trip decisions
    - CAV cost would factor into participants' decisions to purchase personal vehicle or use public transportation
- Concern about costs was tempered by a sense that CAV technology is gradually rolling out so there won't be a sudden increase in vehicle cost

Strategies to help older adults deal with CAV costs

- Participants did not suggest strategies, instead they seemed accepting that increased costs were inevitable and they would pay them

3) Reluctance to give up driving/controlling the car

Things older drivers have to give up to use CAVs

- Flexibility and spontaneity (mentioned by four participants)
    - Because drivers will have to program their destination at the start of the trip and the CAV will plan the route and drive the vehicle to the destination, older drivers will lose the flexibility to make spontaneous stops and route changes
- Option to play loud music
    - Cavs may prevent drivers from setting loud music volumes (mentioned by one participant) or loud music may prevent drivers from interacting with CAVs (mentioned by another participant)
- Control of the driving/operation of the vehicle
    - Drivers must trust that CAVs will stop for obstacles and get safely through snow/ice storms
    - Conversely, as people age it is "nicer" for older drivers to have the car control the driving/operation of the vehicle
    - Plus, giving up control might not end up being that difficult because most people multi-task while driving anyway
- Option to drive over the speed limit

Impact of concessions older drivers will have to make to use CAVs

- Once/if trust is achieved, there are potential benefits for older adults
    - CAVs could relieve stress for older adults during driving
    - CAVs could allow more people to get out and be more independent that cannot now (mentioned by two participants)
        - This could reduce depression associated with mobility challenges
- Fear that older drivers will lose learned reactions/skills from years of driving (mentioned by two participants plus consensus nods)

    - If older drivers must intervene and take over driving it may be more difficult for them to do so effectively

Strategies to overcome reluctance regarding CAVs

- Pairing an older adult with a mentor (like a young person) that the older adult can go back to with questions might be effective
- Design CAVs so older adults can customize the interior to retain some of the features they are familiar with, even if those features no longer work (e.g., steering wheel, brake pedals) (mentioned by two participants plus consensus nods)

4) Concern that technology is user-friendly enough to use independently

Things older adults may need help with to use CAVs

- Giving clear instructions to and being understood by the navigation system
- What happens during a medical emergency and how do people experiencing an emergency get help? (mentioned by three participants)
    - Currently people in distress will pull over, crash, or otherwise seek help. How will CAV know if driver is in distress? Will CAV continue to programmed destination and park with potentially unconscious driver inside and no help alerted?
- Customization in learning how to initially use and continue to use CAVs (mentioned by three participants)
    - Older adults do not want to have to get help from their grandkids every time there is a software update
- How will older adults with service animals use CAVs?

Where can older adults get help from to use CAVs?

- The signals, lights, beacons, and buttons in CAVs should provide the guidance needed for drivers and be designed with fonts and sizes that older adults can see, hear, and understand (mentioned by four participants)
- Adult kids

Where do older adults feel comfortable getting CAV help from?

- Senior centers
- Websites designed for answering questions
    - They could also use Google to obtain Q&As about CAVs
    - YouTube videos combined with a help-line to answer questions
- Help desk for all manufacturers and languages (but probably cost prohibitive and who would provide it?)

Where do older adults feel uncomfortable getting CAV help from?

- IRS and similar government agencies
- People they cannot understand

Frequency older adults will need CAV help?

- Ongoing (consensus nods)

5) Intimidated by the technology

Things that intimidate older adults about CAVs

- Newness
- Unknown
- Loss of understanding and connection to innovation
    - As we get older, we are not the people leading these changes anymore and we lose our connection and understanding of them. You cannot be intimidated when you are the person designing it, but you can when you are on the outside
- Different challenges to use CAVs in rural and urban areas
    - Will the needed infrastructure be in place everywhere? What happens up north where there are no street signs and streets are missing from maps?
    - Will we be moving away from person vehicles in urban settings? How will CAVs change how mass transit works?
    - Will CAV training address how to use them in different environments/settings?
- Using CAVs may impact older adults in other ways beyond transportation
    - If older adults are more independent and getting out more they may have greater exposure to bacteria in shared spaces
- Who is going to own all these vehicles? Government or private interests?
- How will vacation travel work for those who shift to shared/mass transit?

CAV trainers/promoters may need to work harder than with other age groups to appeal to older adults and get their buy-in for CAVs

- The wording of how-to instructions and training is important. Do not talk down to the older adult audience but still make it something they can understand
- Do not throw all the information at older adults at once. Use a stepwise approach – build from the basics then move on
    - Giving older adults a one-hour workshop and sending them off will not work
    - The transition to full automation will not be overnight so for most people you have the time to take smaller steps in getting them there instead of taking a big leap
- Older adults may tend to be unwilling to learn about CAVs if they are overwhelmed
- Receiving peer support and hearing from peers that are already using CAVs will make it feel more natural (mentioned by two participants)
- Make training and gaining experience with CAVS fun
- Build older adults’ confidence with CAVS as they go through training
- Be proactive with outreach – take CAVS to senior centers or auto shows for older adults to experience. Or have CAV open houses at places like MCity.
- Increasing older adults’ knowledge about CAVs will increase their trust in CAVs and that will decrease their intimidation by CAVs

5.2.3 Conclusions

Despite the separate focus on CAV benefits and barriers between groups and the resulting generation of two separate lists of topics for each group, several consistent and/or overlapping themes emerged from both groups and across multiple benefit/barrier topics and should be considered within the context of developing the older adult training and classroom project:

- Participants expect that many older adults will be resistant to using CAVs and they provided several suggestions for how to overcome this including the tone, format and content of messaging and strategy.
- CAV training should be appropriately tailored to older adults' learning styles and stages of CAV acceptance, knowledge, and understanding.
- Older adult CAV training should include opportunities for hands-on experience using CAVs.
- CAV support and training for older adults should be ongoing and not a one-time administration.
- Training that includes partnering older adults with peers and/or trusted mentoring (e.g., children/grandchildren) for initial training and on-going support may be effective.

6. TASK 3: PROJECT TEAM PRESENTATIONS TO STUDENTS

As noted earlier, four presentations were developed by members of the project team and delivered to students enrolled in the U-M Dearborn course HCDE 510 over the course of the term to help them explore issues related to older adults and CAVs. The presentations included: 1) an overview of the project; 2) summary findings from the research synthesis; 3) summary findings from the community engagement; and 4) an industry perspective on older adults and CAVs. Each project team presentation included ample time for discussion with the students and was followed by student presentations on their activities and progress in the class.

7. TASK 4: STUDENT CLASSROOM PROJECT

This project was designed to use the existing curriculum requirements of U-M Dearborn course HCDE 510 as the vehicle for helping students explore issues of older adults and CAVs. To that end, students were required to work in teams on a classroom project that used principles of human-centered design to solve real-world problems relative to older adults and CAVs. Three teams worked on the classroom project. A brief overview of each teams' project (as developed by the team and later used as the abstract for the team's poster presentation) is provided below.

7.1 Team 1 Project

7.1.1 Title
How might we design a GPS tracking companion app to assist caregivers in monitoring the location of seniors with cognitive impairment while riding in autonomous vehicles?

7.1.2 Summary
Retaining independence is an important factor for seniors (people over 65 years old) who still drive. Many seniors voice concerns for driving safety for themselves and their partners and/or senior friends, especially if a senior has cognitive impairment. Based on the themes and feedback from our initial interview, we chose to target caregivers of seniors as the primary user and seniors with mild cognitive impairment as the secondary user who would be riding in the CAV. We wanted to integrate our design into a technology that our target audiences are already used

to. Drawing inspiration from our focus group and their affinity for the app called Life360, we decided to create an app called CompaniON. CompaniON is an app that could be used by caregivers of seniors (primary user) to track the GPS location of a senior CAV rider (secondary user). The app would also help seniors CAV riders locate their parked CAV and communicate with their caregiver(s) if they need assistance.

7.2 Team 2 Project

7.2.1 Title

Improving the in-vehicle experience to help the elderly and their caregivers to feel connected during an emergency and provide trouble-free navigation.

7.2.2 Summary

This project specifically concentrates on investigating elderly people and their emotional needs when considering connected autonomous vehicles. The problem identified was that the elderly need to feel connected to caregivers and/or family members in emergency scenarios. People over the age of 60 were selected to be the users. Those who still drive and those who do not drive were included. Secondary and extreme users were also included, such as caretakers for elderly people and people with varying levels of mobility and cognitive disabilities. Interviews were conducted to help understand the target user groups and their driving habits and their trust and thoughts in general about autonomous vehicles. Keeping our users in mind, we conducted an iterative ideation and prototyping phase. Primary, secondary, and extreme users were utilized during the testing phase to understand which features were most desired and which needed to be re-thought. The ideas incorporated solutions that allow elderly passengers to call a list of contacts who could reroute the vehicle in case of a request, call emergency services and monitor the health of the car and the passenger remotely. The final iterative prototype was created and tested using Figma and provides a solution to the elderly passengers' need to feel connected to their caregivers, especially in an emergency situation.

7.3 Team 3 Project

7.3.1 Title

Navigating in the dark: Designing autonomous driving features to assist visually impaired older adults (Bynum et al., 2023).

7.3.2 Summary

Age-related macular degeneration is a leading cause of blindness worldwide and is one of many limitations for older adults to drive independently. Fully autonomous vehicles present a prospective solution for those who are no longer capable of driving due to low vision, however accessibility features must be implemented to create a safe and effective experience for users with vision impairment to maintain a sense of control. Using a combination of semi-structured user interviews and Wizard of Oz prototyping, our research team created and modified a prototype to aid passengers with age-related macular degeneration to travel comfortably and remain in control while riding in an autonomous vehicle. The final design prototype includes a voice-activated navigation system with three levels of detail to bolster situational awareness, a 360˚ in-car camera to detect both the passenger and objects in front of the vehicle, a retractable microphone for the passenger to be easily registered in the car while speaking, and a physical button on the console-side of the right and left front seats to manually activate the navigation system.

8. TASKS 5 AND 6: DEVELOPMENT AND PRESENTATION OF POSTERS BY THE STUDENTS AND THE PROJECT TEAM

The three student teams developed posters highlighting their classroom project (including research questions, methods, findings, discussion) and presented them in a formal poster session at UMTRI on December 9, 2022. The UMTRI project team also developed and presented posters highlighting the overall project and findings from the research synthesis and community engagement at the session. The poster session was attended by U-M faculty and staff, representatives from government and industry, and other undergraduate and graduate students. Pictures from the poster session are shown below. The posters, as well as general information about the project and biographical information about the project team and the students can also be found on the CCAT website at https://ccat.umtri.umich.edu/events/past/poster-session-inclusive-design/.

Figure 7.1: The project team and the student presenters

Figure 7.2: CCAT Director Henry Liu (left) and project Co-Investigator David W. Eby

Figure 7.3: Team 1 discusses their posters with attendees

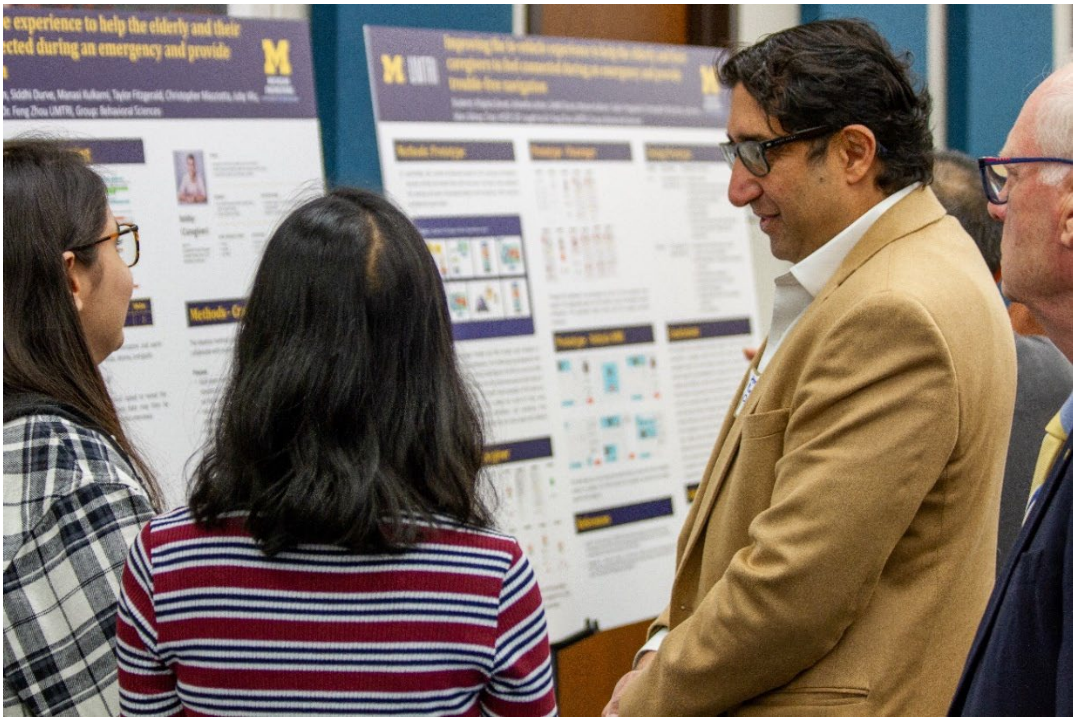

Figure 7.4: Team 2 discusses their posters with attendees

Figure 7.5: Team 3 discusses their posters with an attendee

9. TASKS 7: EVALUATION

The project was, in part, evaluated through pre- and post-surveys of students to measure changes in knowledge about older adults and CAVs. In this section, we describe the methods used to conduct the evaluation and the resulting findings.

9.1 Methods

The pre- and post-surveys used the same set of questions to measure knowledge and attitudes, with items mapping directly to information included in the presentations given by the UMTRI project team. The second survey also sought feedback from students about the classroom project (e.g., how useful they found it, challenges in completing it, suggestions for improvements for future use among other students). The surveys were pre-tested to make sure that items were clear and easy to understand. The surveys were designed to take between 10 and 15 minutes for respondents to complete. Copies of the pre- and post- survey instruments can be found in Appendix A.

The pre-survey was administered to students prior to any discussion of the project or delivery of the presentations by the UMTRI project team (September 2022). The post-survey was administered after the classroom project was completed but before the formal poster session (December 2022). Both surveys were administered using the online survey program, Qualtrics, with responses anonymized. Students were given a link to the surveys and completed the surveys online. Upon completion of the pre-survey, Qualtrics randomly generated a numeric code for each participant that he/she used to access the post-survey. This allowed participants' pre- and post-surveys to be linked for analysis while preserving the students' anonymity.

9.2 Findings

The final sample analyzed for the pre- and post-surveys included 17 of the 25 students in the class (unless otherwise noted). These were the students who completed both the pre-test and the post-test. Although 21 students completed the pre-test and 21 students completed the post-test, four students completed the pre-test but not the post-test, and four students completed the post-test but not the pre-test.

9.2.1 Sample Characteristics

Student ages ranged from 22-45, with a Mean of 27.0 and standard deviation (SD) of 6.0. Other characteristics are included in Table 9.1 below.

Table 9.1: Sample Characteristics

	n	%
Sex (n=17)		
Male	2	11.8
Female	15	88.2
Currently Employed (n=17)		
Yes	10	58.8
No	7	41.2
If employed, full- or part-time (n=10)		
Full-time	8	80.0
Part-time	2	20.0
Industry and Occupation (n=10)		
Automotive Industry	4	40.0
Other Industry	2	20.0
Education	1	10.0
Other	3	30.0

9.2.2 Knowledge Scores

Respondents received 1 point for each correct response to the 13 knowledge items in each of the pre- and post-tests. Thus, the highest possible score for each survey was 13. Table 9.2 below provides information on the range, mean, and SD for each survey, as well as the change from the pre- to post-survey.

Table 9.2: Ranges, Means and SDs for Pre- and Post-Surveys

	Range	Mean	SD
Pre-Test Score	0-10	5.4	2.6
Post-Test Score	2-11	6.8	2.4
Change from Pre to Post	-2 to +6	+1.4	2.1

A paired t-test was used to examine the statistical significance of any change in knowledge between the pre- and post-test. Based on this test, knowledge increased significantly from the pre-test to the post-test (t=2.60 (df=16), p=0.020). However, as seen in the table, the increase was quite modest.

9.2.3 Feedback on Classroom Project

The post-survey included two items to obtain feedback from students about the classroom project. Responses are presented below for all 21 students who completed the post-test. Students were asked: On a scale of 1-7 ranging from 1 (Not At All) to 7 (Very), please rate how useful the presentations the UMTRI-Toyota team made during your class were for your group project? Results are provided in Table 9.3 below.

Table 9.3: Usefulness of Project Team Presentations

	n	%
1 Not at all useful	0	
2	1	4.8
3	0	
4	1	4.8
5	0	
6	11	52.4
7 Very useful	8	38.1

Students were also asked**:** How did you use information from the UMTRI-Toyota presentations in your group project? A total of eight responses were provided to this question. They are presented verbatim below.

- Considered factors that applied to our project.
- I believe the Toyota presentation was given the same evening as the final presentation so there was no opportunity for their content to mode our work. However, the presentation was still helpful and provided good insight as to what a career in UX at Toyota might look like. If I misinterpreted this question and it refers to all earlier guest presentations (by Jennifer and her team), then I would say they were highly influential. It was her literature review and feedback regarding cognitive impairment that led my team to refine our work significantly ahead of the final presentation.
- I save a few screen captures from the presentations so I could look back & learn the processes they used and research findings. I wanted to be able to reflect on the presentation through the course. These are valuable when learning about HCDE for the first time.
- It brought more understanding and awareness to our target audience.
- Referencing data.
- We made sure to allow the participants to feel comfortable during our interviews to keep the discussion open and honest.
- We used this to understand how we could narrow our research question.
- We referenced the design process in our iteration sessions.

10.TASKS 8: RECOMMENDATIONS

Based on the collective findings from the earlier tasks, a set of recommendations was developed to inform future efforts to educate students in this area. Collectively, the recommendations address the various components of the experiential learning framework used in this project. As noted earlier, these included: student exploration of issues of older adult accessibility, acceptability, affordability, and other aspects of inclusion related to CAVs through presentations by the research team; student engagement with these issues through a classroom project; student reflection on what they learned; and student communication of what they learned through a poster session attended by university faculty and students, and representatives from government, business, and industry.

Recommendations were also developed specifically for the design and deployment of CAVs for older adults. Both sets of recommendations are listed below.

10.1 Recommendations for Future Efforts to Educate Students

Recommendation 1. Aims and focus of overall project need to align with and support the curriculum of the course selected for the project.

Whether the course selected for the project is an undergraduate or graduate course, and whether it is an engineering course (e.g., human centered design course as in the current project) or non-engineering course (e.g., transportation planning or public health course on injury prevention), efforts to sensitize students in the class to issues of older adults and CAVs need to be harmonized to the course content and goals. Thus, the presentations/discussions by the project team may need to be tailored to the specific course. More importantly, the classroom project will need to be developed in consultation with the course instructor to ensure that it is not only consistent with the course objectives but that it does not impose undue burden on the students or instructor.

Recommendation 2. Project team presentations/discussions should occur early in the course and be delivered in one unified session rather than broken up during the course to the extent possible.

Based on the experience of the current project, we believe that the presentations would have greater impact if they were delivered together in one session at the beginning of the course, rather than given separately over the course term. This is due, not only to the interrelationships between the various presentation topics and the need to connect all the pieces together, but also because the information contained in the presentations can play an important role in informing both the planning and implementation of the classroom projects if provided early enough in the course.

Recommendation 3. Project team presentations should be given in-person to the extent possible to facilitate interaction between students and team members.

In the current project, many of the students enrolled in the course participated virtually rather than in-person, especially those who were geographically distant from the Dearborn site of the course. Therefore, the project team also participated virtually. For classes that are taught in-person, it would be preferable for the project team to present in-person to better promote dialog and free-flowing exchange of ideas.

Recommendation 4. Provide students with fact sheets (electronic/hard copy) that succinctly summarize the most salient take-aways from the presentations.

Given the amount of detailed information contained in the presentations and the fact that many of the students will not have been exposed to much of the information before, it makes sense to summarize the salient points that we want to leave students with and provide those summaries to them, preferably in both electronic and hard copy formats. This will allow students to revisit and review the information throughout the classroom project.

Recommendation 5. The project team presentations should continue to focus on the four broad topics covered in the current project, albeit with some modifications to meet the needs of the course.

In the current project, four presentations were given to students. The first was a brief overview of the project to give students some background information. The second reported on the research synthesis conducted by the project team that identified salient findings from the scientific literature. The third reported on the community engagement activities conducted with older adults themselves that explores their needs, preferences, and broader perceptions about CAVs and mobility. The final presentation was given by the industry champion for the project and presented an industry perspective on the issues of older adults and CAVs. Collectively, these four topics (and the activities supporting them) provide valuable information for students and should continue to be included in future projects. There may need to be some tailoring to fit the specific course (e.g., topics covered in the research synthesis may need to be adjusted to ensure they are closely related to the course).

Recommendation 6. In presenting on the research synthesis and community engagement, it is important to discuss not only the findings but also the methods used to conduct these activities.

Depending on the course selected for future projects, students may be required to gather their own information, either through reviewing the literature or reaching out to older adults in some way, as was done in this project. Therefore, it is important to continue to include in the project team presentations, information on the scientific approach and methods used to collect the data being presented to the students. This can be very useful to them as they plan and implement their own classroom projects, especially for those without previous research experience.

Recommendation 7. The role of the research team in interacting with the students should extend beyond simply presenting/discussing information on older adults and CAVs to include providing feedback throughout the classroom project process.

The research team has valuable experience and expertise that can be shared with students throughout the classroom project process. This includes not only their initial planning for and implementation of their projects, but also their reflection on what they have learned from the projects.

Recommendation 8. The development and presentation of posters by students highlighting their classroom projects is an appropriate and preferred approach for communicating the outcomes and lessons learned from the projects.

The process of developing and presenting posters was a very effective way for students to communicate what they learned in their classroom project. It also provided an excellent opportunity for students to meet and interact with a wide variety of stakeholders including faculty and students, as well as representatives from government, business, and industry.

10.2 Recommendations for Design and Deployment of CAVs for Older Adults

Recommendation 9. CAV design and deployment should be responsive to declines in multiple areas of functioning that are associated with aging, including perception, cognition, and psychomotor functioning.

Older adults may experience declines in perceptual, cognitive, and psychomotor functioning due to medical conditions that become more prevalent with age and/or the medications used to treat these conditions. These declines can have adverse effects on driving safety and comfort. CAVs should be designed to accommodate the needs of these individuals. Example features include: allowing older adults to control the vehicle using their voice or gestures; making the vehicle easy to get in and out of; and making the vehicle controls easy to see and use. Vehicles should also be comfortable and spacious, with ample legroom and headroom.

Recommendation 10. At the same time, the heterogeneity among older adults, in terms of both abilities and perceptions, suggests that effective deployment of CAVs among this population will require not only an understanding of older adults' functional needs as drivers, but also how their current and future lifestyles can be best accommodated.

Evidence suggests that older adults tend to see themselves as younger than their chronological age and do not equate their age-related declines as disabilities. This has led to the argument that vehicle design and marketing for older adults should focus on life events and circumstances rather than age per se.

Recommendation 11. CAV design and deployment should address the concerns and expectations of older adults by ensuring that features and functionality are communicated accurately, and that training is available for understanding and using the technology.

Accurate information about the features and functionality of CAVs is needed so that older adults' expectations better match the realities of the technology. In addition, ongoing training opportunities are needed that are tailored to older adults. Such training should be: hands-on to facilitate acceptance and use; specifically tailored to the ways that older adults learn; and include partnering older adults with peers and/or trusted mentoring (e.g., children/grandchildren).

Recommendation 12. Vehicle design engineers, as well as students planning to work in this area, should include members of the aging population as full participants in design testing.

The development of HMI guidelines and the design process for CAVs often occurs in the absence of consideration of older adult needs and preferences. Therefore, it is important to increase the participation of older adults in the testing process.

Recommendation 13. In thinking about design and deployment features and strategies, the needs and preferences of both older adults themselves and their informal caregivers providing transportation assistance should be considered.

Many older adults received transportation assistance from informal caregivers, including family members and friends. Thus, their needs and preferences need to be taken into account.

Recommendation 14. Clear and concise information should be provided to older adults to improve their needed level of situation awareness.

Older adults may not be able to process as much information as younger adults, so it is important to provide clear and concise information about the vehicle's surroundings and actions to improve their situation awareness. This information should be easy to understand and should not be overwhelming.

Recommendation 15. Older adults should be given control over the vehicle by providing customized options.

Older adults may feel more comfortable and in control if they can customize their ride experience. This could include the ability to choose the route, the speed, and the level of automation.

11. OUTPUTS, OUTCOMES, AND IMPACTS

This project resulted in several important research outputs, outcomes, and impacts related to ensuring that the design and deployment of CAVs are responsive the needs and preferences of older adults, particularly in the areas of accessibility, acceptability and other aspects of inclusion. These outputs, outcomes, and impacted are highlighted in Appendix B.

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13. APPENDICES

13.1 Appendix A: Pre- and Post-Survey Instruments

CCAT Survey 1

Note: The correct answers to the survey items are underlined.

Start of Block: Consent

Q4 **Welcome to the Online Survey about Older Drivers (HUM00222755)**
Dr. Lisa Molnar of the University of Michigan Transportation Research Institute (UMTRI) invites you to participate in a study to evaluate ways of helping students learn about older drivers. The study is funded by the Center for Connected and Automated Transportation at the University of Michigan. It is being conducted by UMTRI.

If you agree to be part of the research study, you will be asked to complete two online surveys about information presented during HCDE 510 (one now and one at the end of the semester). We expect each survey to take 5 to 10 minutes to complete.

Participating in this study is completely voluntary. Even if you decide to participate now, you may change your mind at any time, for any reason. You may choose not to answer any question for any reason. Your decision to participate or not participate will not impact your standing or grade in HCDE 510. Dr. Zhou will not know who participates in the study and who does not. Your answers to the survey questions will not impact your standing or grade in HCDE 510.

We will not collect your name, email address, UM uniqname, telephone number or any information that can identify you. Information that can identify you will not be linked to your survey responses in any way. A numeric ID number will be randomly generated for you at the end of the first survey and you will use that number to access the second survey. A link to the second survey will be emailed to all students in HCDE 510 at end of the semester.

You may not receive any direct benefits from being in this study. The results of this study may help improve future education programs for engineering students. If you have any questions about this study, you may contact **Dr. Lisa Molnar at (734)-764-5307.**

As part of their review, the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board (IRB) has determined that this study is no more than minimal risk and exempt from on-going IRB oversight.

By selecting “Start the survey” below, you are consenting to participate in this research.

If you do not wish to participate, click in the “x” in the top corner of your browser to exit.

End of Block: Consent

Start of Block: Q1-Q16

Q1 **(Q1) Please enter your age in years:**

____

Skip To: End of Survey If Condition: (Q1) Please enter your age ... Is Less Than 18. Skip To: End of Survey.

Q5 **(Q2) Which of the following characterizes population trends in the United States?**

- ○ The population is shrinking. (1)
- ○ The population is staying relatively the same. (2)
- ○ The population is getting younger. (3)
- ○ <u>The population is getting older.</u> (4)
- ○ All of the above. (5)
- ○ None of the above. (6)

Q4 **(Q3) Which of the following statements are true?**

- ○ Older adults in urban areas prefer to get around by bus. (1)
- ○ Older adults in rural areas prefer to get around by getting rides with friends or family. (2)
- ○ <u>Older adults prefer to drive themselves.</u> (3)
- ○ Once older adults stop driving, they still have about 2-4 years of life left to get around. (4)
- ○ All of the above. (5)
- ○ None of the above. (6)

Q5 **(Q4) Which of the following is NOT a category that is generally used to describe declines in functioning among older adults?**

- ◯ Psychomotor (1)
- ◯ Perceptual (2)
- ◯ <u>Psychological</u> (3)
- ◯ Cognitive (4)
- ◯ All of the above (5)
- ◯ None of the above (6)

Q6 **(Q5) Which of the following is NOT an adverse consequence of driving cessation that has been identified in research studies?**

- ◯ Loss of independence and freedom (1)
- ◯ Increased depressive symptoms (2)
- ◯ Increased risk of nursing home placement (3)
- ◯ <u>Increased risk of moving in with adult children</u> (4)
- ◯ All of the above (5)
- ◯ None of the above (6)

Q7 **(Q6) Which of the following statements is true?**

- ◯ <u>Older adults see themselves as 10-15 years younger than their chronological age.</u> (1)
- ◯ Older adults and people with disabilities generally share the same self-perceptions and aspirations about their functioning. (2)
- ◯ Older adults want products marketed specifically to them and their specific needs. (3)
- ◯ All of the above (4)
- ◯ None of the above (5)

Q8 **(Q7) Which selection criterion could be used to focus a literature review search?**

- ◯ Choose a time period for publication (e.g., 2010-2022) (1)
- ◯ Limit to certain geographic areas (e.g., US and Europe) (2)
- ◯ Select the type of documents allowable (e.g., journal article, dissertations, websites) (3)
- ◯ Document is required to be in a specific language (e.g., English) (4)
- ◯ <u>All of the above</u> (5)
- ◯ None of the above (6)

Q9 **(Q8) If your literature review must have empirical data from each source, what kinds of publications would likely be excluded from your search?**

- ○ Commentaries/opinion pieces (1)
- ○ Peer-reviewed journal articles (2)
- ○ Technical reports (3)
- ○ Conference proceedings (4)
- ○ Government reports (5)
- ○ All of the above (6)
- ○ None of the above (7)

Q10 **(Q9) Which steps are NOT involved in conducting a traditional literature review?**

- ○ Develop inclusion/exclusion criteria to guide the review (1)
- ○ Identify topics to be included in the review (2)
- ○ Choose a statistical analysis program to analyze the data collected (3)
- ○ Develop search terms to capture how topics may be represented in the literature (4)
- ○ Synthesize the information gathered (5)
- ○ All of the above (6)
- ○ None of the above (7)

Q11 **(Q10) Which of the following are potential benefits of Automated Driving Systems (ADS), according to the US Department of Transportation?**

- ○ Safety (1)
- ○ Mobility (2)
- ○ Economic/societal (3)
- ○ Environmental (4)
- ○ <u>All of the above</u> (5)
- ○ None of the above (6)

Q12 **(Q11) Which of the following are true?**

- ○ As the level of automation increased, older adults reported more positive opinions of safety, trustworthiness, enjoyability, reliability, comfort, perceived ease-of-use, and attractiveness. (1)
- ○ Older men have less positive attitudes toward ADS technologies than older women. (2)
- ○ <u>Older adults have concerns about ADS not being able to manage the hand-over of control if an ADS were to fail or encounter a situation outside of its operational domain.</u> (3)
- ○ Older adults’ attitudes toward ADS technology are not influenced by personal experience with the technology. (4)
- ○ All of the above. (5)
- ○ None of the above. (6)

Q13 **(Q12) What is the most common way older adults report that they use to learn about new advanced driver assistance technologies in their car?**

- ○ The Internet (1)
- ○ The dealer (2)
- ○ <u>Figure it out by themselves</u> (3)
- ○ The owner's manual (4)
- ○ All of the above (5)
- ○ None of the above (6)

Q14 **(Q13) Which of the following are true about qualitative research techniques?**

- ○ <u>Results are not generalizable, but nominal and focus groups are effective methods for obtaining input from small groups.</u> (1)
- ○ In focus groups, the participants should reach a consensus before the moderator asks a new question. (2)
- ○ If focus groups are audio-recorded, field notes can be eliminated from the research process because they are not likely to add useful information to the recorded data. (3)
- ○ In nominal groups, it helps to assign one participant to be the main speaker for the group. (4)
- ○ All of the above (5)
- ○ None of the above (6)

Q15 **(Q14) When analyzing focus group data, what should researchers consider when identifying themes, concepts, and categories that emerge from discussions?**

- ◯ How often an opinion was repeated (1)
- ◯ How many different participants stated an opinion (2)
- ◯ How consistent participants were in their opinions (3)
- ◯ How much intensity was behind an opinion (4)
- ◯ A and B only (5)
- ◯ <u>All of the above</u> (6)

Q16 **(Q15) Are you…**

- ◯ Male (1)
- ◯ Female (2)
- ◯ Other (Please specify) (3) ____
- ◯ Prefer not to say (4)

End of Block: Q1-Q16

Start of Block: Q16 - Currently Employed?

Q17 **(Q16) Are you currently employed in addition to being a student?**

- ◯ Yes (1)
- ◯ No (2)

End of Block: Q16 - Currently Employed?

Start of Block: ID Number

Q23 **Here is your Random ID Number: ${e://Field/Random%20ID}**

Please copy this number and save it someplace you will remember. **You will need this number to complete the follow-up survey at the end of the semester.**

Once you have copied your ID Number, please click Submit to finish the survey.

End of Block: ID Number

Start of Block: Follow-up employment questions

Q18 **(Q17) Are you working…**

- ○ Full-time (1)
- ○ Part-time (2)
- ○ Other (Please specify) (3) ____
- ○ Prefer not to answer (4)

Q19 **(Q18) What is your occupation?**

____

Q20 **(Q19) Which of the following best describes your employer?**

- ○ Government (1)
- ○ Automotive industry (2)
- ○ Other industry (3)
- ○ Education (4)
- ○ Other (Please specify) (5) ____

End of Block: Follow-up employment questions

CCAT Survey 2

Note: The correct answers to the survey items are underlined.

Start of Block: Consent

Intro **Welcome to the Second Online Survey about Older Drivers (HUM00222755)**
Dr. Lisa Molnar of the University of Michigan Transportation Research Institute (UMTRI) invites you to participate in a study to evaluate ways of helping students learn about older drivers. The study is funded by the Center for Connected and Automated Transportation at the University of Michigan. It is being conducted by UMTRI.

If you agree to be part of the research study, you will be asked to complete an online survey about information presented during HCDE 510. We expect the survey to take 5 to 10 minutes to complete. You may have completed a similar survey for this study earlier in the semester.

Participating in this study is completely voluntary. Even if you decide to participate now you may change your mind at any time, for any reason. You may choose not to answer any question for any reason. Your decision to participate or not participate will not impact your standing or grade in HCDE 510. Dr. Zhou will not know who participates in the study and who does not. Your answers to the survey questions will not impact your standing or grade in HCDE 510.

We will not collect your name, email address, UM uniqname, telephone number or any information that can identify you. Information that can identify you will not be linked to your survey responses in any way.

To start the survey you will need to enter the ID number you received at the end of the first survey. If you do not know your ID number or you did not complete the first survey, please contact jzak@umich.edu for assistance.

You may not receive any direct benefits from being in this study. The results of this study may help improve future education programs for engineering students.

If you have any questions about this study, you may contact **Dr. Lisa Molnar at (734)-764-5307.**

The University of Michigan Institutional Review Board Health Sciences and Behavioral Sciences has determined that this study is exempt from IRB oversight.

By selecting “Start the survey” below, you are consenting to participate in this research.

If you do not wish to participate, click in the “x” in the top corner of your browser to exit.

End of Block: Consent

Start of Block: Prompt for ID number

Q22 Please enter the ID number you were given at the end of the first survey:
(contact jzak@umich.edu or 734-615-4740 if you need assistance)

____

End of Block: Prompt for ID number

Start of Block: Q1-Q16

Q1 **Please enter your age in years:**

____

Skip To: End of Survey If Condition: (Q1) Please enter your age ... Is Less Than 18. Skip To: End of Survey.

Q2 **Which of the following characterizes population trends in the United States?**

- ○ The population is shrinking. (1)
- ○ The population is staying relatively the same. (2)
- ○ The population is getting younger. (3)
- ○ The population is getting older. (4)
- ○ All of the above. (5)
- ○ None of the above. (6)

Page Break

Q3 **Which of the following statements are true?**

- ◯ Older adults in urban areas prefer to get around by bus. (1)
- ◯ Older adults in rural areas prefer to get around by getting rides with friends or family. (2)
- ◯ <u>Older adults prefer to drive themselves.</u> (3)
- ◯ Once older adults stop driving, they still have about 2-4 years of life left to get around. (4)
- ◯ All of the above. (5)
- ◯ None of the above. (6)

Page Break

Q4 **Which of the following is NOT a category that is generally used to describe declines in functioning among older adults?**

- ◯ Psychomotor (1)
- ◯ Perceptual (2)
- ◯ <u>Psychological</u> (3)
- ◯ Cognitive (4)
- ◯ All of the above (5)
- ◯ None of the above (6)

Page Break

Q5 **Which of the following is NOT an adverse consequence of driving cessation that has been identified in research studies?**

- ◯ Loss of independence and freedom (1)
- ◯ Increased depressive symptoms (2)
- ◯ Increased risk of nursing home placement (3)
- ◯ <u>Increased risk of moving in with adult children</u> (4)
- ◯ All of the above (5)
- ◯ None of the above (6)

Page Break

Q6 **Which of the following statements is true?**

- ◯ <u>Older adults see themselves as 10-15 years younger than their chronological age.</u> (1)
- ◯ Older adults and people with disabilities generally share the same self-perceptions and aspirations about their functioning. (2)
- ◯ Older adults want products marketed specifically to them and their specific needs. (3)
- ◯ All of the above (4)
- ◯ None of the above (5)

Page Break

Q7 **Which selection criterion could be used to focus a literature review search?**

- ◯ Choose a time period for publication (e.g., 2010-2022) (1)
- ◯ Limit to certain geographic areas (e.g., US and Europe) (2)
- ◯ Select the type of documents allowable (e.g., journal article, dissertations, websites) (3)
- ◯ Document is required to be in a specific language (e.g., English) (4)
- ◯ <u>All of the above</u> (5)
- ◯ None of the above (6)

Page Break

Q8 **If your literature review must have empirical data from each source, what kinds of publications would likely be excluded from your search?**

- ◯ <u>Commentaries/opinion pieces</u> (1)
- ◯ Peer-reviewed journal articles (2)
- ◯ Technical reports (3)
- ◯ Conference proceedings (4)
- ◯ Government reports (5)
- ◯ All of the above (6)
- ◯ None of the above (7)

Page Break

Q9 **Which steps are NOT involved in conducting a traditional literature review?**

- Develop inclusion/exclusion criteria to guide the review (1)
- Identify topics to be included in the review (2)
- Choose a statistical analysis program to analyze the data collected (3)
- Develop search terms to capture how topics may be represented in the literature (4)
- Synthesize the information gathered (5)
- All of the above (6)
- None of the above (7)

Page Break

Q10 **Which of the following are potential benefits of Automated Driving Systems (ADS), according to the US Department of Transportation?**

- Safety (1)
- Mobility (2)
- Economic/societal (3)
- Environmental (4)
- All of the above (5)
- None of the above (6)

Page Break

Q11 **Which of the following are true?**

- As the level of automation increased, older adults reported more positive opinions of safety, trustworthiness, enjoyability, reliability, comfort, perceived ease-of-use, and attractiveness. (1)
- Older men have less positive attitudes toward ADS technologies than older women. (2)
- <u>Older adults have concerns about ADS not being able to manage the hand-over of control if an ADS were to fail or encounter a situation outside of its operational domain.</u> (3)
- Older adults' attitudes toward ADS technology are not influenced by personal experience with the technology. (4)
- All of the above. (5)
- None of the above. (6)

Page Break

Q12 **What is the most common way older adults report that they use to learn about new advanced driver assistance technologies in their car?**

- The Internet (1)
- The dealer (2)
- <u>Figure it out by themselves</u> (3)
- The owner's manual (4)
- All of the above (5)
- None of the above (6)

Page Break

Q13 **Which of the following are true about qualitative research techniques?**

- ◯ Results are not generalizable, but nominal and focus groups are effective methods for obtaining input from small groups. (1)
- ◯ In focus groups, the participants should reach a consensus before the moderator asks a new question. (2)
- ◯ If focus groups are audio-recorded, field notes can be eliminated from the research process because they are not likely to add useful information to the recorded data. (3)
- ◯ In nominal groups, it helps to assign one participant to be the main speaker for the group. (4)
- ◯ All of the above (5)
- ◯ None of the above (6)

Page Break

Q14 **When analyzing focus group data, what should researchers consider when identifying themes, concepts, and categories that emerge from discussions?**

- ◯ How often an opinion was repeated (1)
- ◯ How many different participants stated an opinion (2)
- ◯ How consistent participants were in their opinions (3)
- ◯ How much intensity was behind an opinion (4)
- ◯ A and B only (5)
- ◯ All of the above (6)

End of Block: Q1-Q16

Start of Block: Group Project questions

Q40 On a scale of 1-7 ranging from 1 (Not at All) to 7 (Very), please rate how useful the presentations the UMTRI-Toyota team made during your class were for your group project?

- ○ 1 Not At All Useful (4)
- ○ 2 (5)
- ○ 3 (6)
- ○ 4 (7)
- ○ 5 (8)
- ○ 6 (9)
- ○ 7 Very Useful (10)

Q41 **How did you use information from the UMTRI-Toyota presentations in your group project?**

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End of Block: Group Project questions

13.2 Appendix B: Outputs, Outcomes, and Impacts

Synopsis of Performance Indicators Part I and II

This project involved the participation of 25 graduate students enrolled in the U-M Dearborn course HCDE 510, a graduate course on human centered design and engineering taught by Dr. Feng Zhou, an Assistant Professor in Industrial and Manufacturing Systems Engineering, College of Engineering and Computer Science at U-M Dearborn. During the project, the U-M research team disseminated project results through two oral presentations at conferences/meetings, and one peer-reviewed conference papers (see following section for fuller detail and references).

Outputs

This project resulted in several important research outputs that have the potential to improve the effectiveness and safety of the transportation system, particularly in the areas of accessibility, acceptability and other aspects of inclusion. These are highlighted below.

Peer-reviewed Papers at Conferences

Bynum, L., Parker, J., Lee, K., Nitschke, N., LaFlam, M., Marcussen, J., Taleb, J., Dogan, A., Molnar, L.J., Avetisyan, L., and Zhou, F. (2023). Navigating in the dark--designing autonomous driving features to assist old adults with visual impairments. In *Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications,* 1-8.

Presentations at Conferences and Meetings

Molnar, Lisa J. (September 13, 2022). Project overview and status to date. Invited presentation to *Mcity Accessibility Working Group*. Ann Arbor, MI.

Molnar, Lisa J. & Yi, Ping. (April 4, 2023). Promoting inclusive design and deployment of connected and automated vehicles for older adults through education and training of engineering students and older adults. Invited presentation to CCAT's *2023 Global Symposium on Mobility Innovation*. Ypsilanti, MI.

Molnar, Lisa J., Zhou, Feng., Eby, David.W., Yi, Ping, St. Louis, R., Zakrajsek, J., Zanier, N. (July 27, 2023). Promoting inclusive design and deployment of connected and automated vehicles for older adults through education of engineering students. Peer-reviewed presentation at *Human Computer Interface International (HCII) Conference*. Part of HCII Parallel Session: Emerging and Future Technologies to Support the Safe Mobility of Older Adults. Copenhagen, Denmark.

Other Outputs

1. Techniques and recommendations were developed that integrate experiential learning with principles of diversity and inclusion that can be used in an educational setting for engineering

and other students.

2. Survey instruments were developed to evaluate effectiveness of the classroom project. These instruments can serve as a foundation for the evaluation of other future efforts.

Outcomes

1. The project team's research synthesis and community engagement activities resulted in strengthening the body of knowledge relative to older adults and CAVS. Particular areas of increased knowledge include: 1) cognitive, psychomotor, and perceptual abilities that decline with age; 2) ADS and vehicle technology issues (e.g., how older adults understand, learn about, and use such technologies, and barriers to use including accessibility, affordability, inclusion, acceptability); attitudes related to trust and acceptance; and 3) design of ADSs and ADS deployment demonstration (e.g., inclusion of older adults in ADS design, challenges in deployment, successful strategies for deployment, and ADS research involving older adults).

2. The project resulted in increased understanding and awareness by graduate engineering students about issues related to older adult accessibility, acceptability, and other aspects of inclusion relative to CAVs. The students created posters to that highlight lessons learned about these issues that came out of the classroom project. These posters were shared with a diverse audience of faculty and students, as well representatives from government, business, and industry.

3. The inclusion of an industry champion has provided an opportunity not only for the champion to share an industry perspective with the students, but also for the champion to gain new knowledge about issues related to older adults and CAVs and potential strategies identified by the students for improving older adult accessibility, acceptability, and other aspects of inclusion relative to CAVs.

Impacts

We hope to see important long-term impacts from this project and any further projects based on it. Specifically, we hope to see important impacts on transportation education (resulting in an increase in the pool of trained professionals) and ultimately the design and deployment of CAVs for older adults with regard to accessibility, acceptability and other aspects of inclusion.