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Human factors, user requirements, and user acceptance of ride-sharing in automated vehicles

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Human Factors, User Requirements, and User Acceptance of Ride-Sharing In Automated Vehicles

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Discussion Paper 2017 • 10

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Human Factors, User Requirements, and User Acceptance of Ride-Sharing in Automated Vehicles

Discussion Paper No. 2017-10

Prepared for the Roundtable on

Cooperative Mobility Systems and Automated Driving
(6-7 December 2016)

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Abstract

This paper provides an overview of the social-psychological factors that are likely to influence the trust and acceptance of shared SAE Level 4 Automated Vehicles (AVs). It begins with a short summary of what influences users' engagement in ride-sharing for conventional vehicles, followed by the factors that affect user acceptance and trust of robotic systems. Using studies of human robot interaction (HRI), recommendations are made on how to improve users' trust, acceptance and use of shared AVs. Results from real-world studies and on-line surveys provide some contradictory views regarding willingness to accept and use the systems, which may be partly due to the fact that on-line users have not had actual interactions with AVs. We recommend that the pathway to adoption and acceptance of AVs should be incremental and iterative, providing users with hands-on experience of the systems at every stage. This removes unrealistic, idealised, expectations, which can ultimately hamper acceptance. Manufacturers may also use new technologies, social-networks and crowd-sourcing techniques to receive feedback and input from consumers themselves, in order to increase adoption and acceptance of shared AVs.

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Introduction

This paper offers an overview of some of the social-psychological factors likely to affect car- and ride-sharing for automated vehicles (AVs), providing an indication of the issues that will affect if, how and when citizens will need, utilise and be prepared to pay for automated ride-sharing systems. It is hoped this information can be used by policy makers and city authorities, when attempting to establish the best model for deploying such systems. The paper summarises key results from a number of recent surveys conducted on citizens around the globe, and the small number of actual demonstration projects, where users' views are sought during AV trials. However, likely caveats exist for both sets of data: the former simply rely on participants' image or perception of the systems, as portrayed by the popular/social media, or may well be developed following the descriptions provided by the survey questions/investigator. On the other hand, large-scale and commercially viable AVs, which are shown to be fully reliable and operating at an optimal level, are not yet available for general public use1. In addition, most such vehicles are currently based on prototypes, which are being tested to identify any operational and technological shortcomings. Assessments include how such AVs can be deployed in the current road network, and how the fast developing (but not yet optimal) mapping and communications technologies influence successful operation. Consequently, seeking users' views of their benefit will likely reflect such shortcomings, a factor which must be taken into account when assessing user response to current AVs.

Therefore, as well as considering studies which take users' impression of AVs for mass-transit use and ride-sharing purposes into account, this paper will provide a short summary of our current understanding of the social-psychological factors that have contributed to the success, or otherwise, of conventional ride-sharing schemes. This will include a consideration of if, and how, these factors are likely to be affected by what is surely the fundamental difference between the AV and conventional vehicles: the driver. Here, the analysis will mostly be based on SAE Level 4 vehicles (SAE, 2016), which, for legal and safety reasons, are likely to have an operator present, at least for the foreseeable future (DfT, 2015). It is also worth mentioning that this paper only considers the potential ride-sharing opportunities of publically-owned or -used version of such vehicles, rather than those owned by individuals, for private use. At present, the former category of vehicle has been predominantly deployed at low speeds in urban settings, and is electrically powered. The primary purpose of these vehicles is to provide first mile/last mile transit solutions for the urban environment, and they are also designed to contribute to the reduction of transport-related noise and emissions. Since successful deployment of this form of AV is likely to rely heavily on user acceptance, buy-in, and uptake, an understanding of how these services assimilate with already established public transport systems is crucial. Another important factor to consider here is whether this category of transit provides a 'superior' service to the consumer, for instance in terms of total journey time, value for money, network and locations served. Finally, we need to understand how these forms of AV complement (or affect the use of) other modes of transport, including the users' own vehicle.

In preparing the first draft of this paper for the OECD round table discussion, the authors were asked to focus on a number of main topics, as outlined below:

1. User willingness to share a small unattended vehicle with strangers
2. User willingness to trust AV technology -- how to achieve adequate, but not excessive, trust?
3. Interactions of AVs with pedestrians and bicyclists

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[1] At the time of writing, data from only one or two publically-funded projects testing fully-automated (SAE level4) ride-sharing AVs were available to the authors. However, we are also aware that many more such studies are currently in progress, with a number also considering the social-psychological aspects discussed here.

4. Managing user expectations or mental models about AV capabilities
5. Realistic opportunities to serve mobility-impaired users (children, seniors, handicapped)

Therefore, broadly speaking, the paper focusses on the above concepts, although additional content is provided, where appropriate, to strengthen some of the arguments. This includes a short overview of the main social-psychological factors affected the use of shared conventional vehicles, which we assumed would also users' willingness to shared AVs.

Overview of social-psychological factors affecting the use of shared conventional vehicles

To date, a large number of studies have considered the success of car and ride-sharing with conventional vehicles. However, in a recent literature review of the area, focussing in particular on the transfer aspect of a public transport trip, Chowdhury and Ceder (2016) emphasise that much of the research has thus far concentrated on improving and understanding the operational aspects of the trips, rather than understanding the psychological and policy aspects of such behaviour.

A number of such schemes have been in place for over three decades, including, for example, those arranged by organisations for their employees (see e.g. Dueker et al., 1977). The introduction of new 'apps' and on-line technologies has also meant that remotely organised car and ride-sharing schemes are increasingly on the rise (see below). As with AVs, the main motivation for the introduction of such conventional ride-sharing schemes has been based on the desire to reduce:

- traffic volume, fuel use and any associated emissions; (IEA, 2005; Minett and Pearce, 2011)
- the need for parking spaces, and;
- the cost of travel for its users (TDM Encyclopaedia, 2012);
- At the same time, they are considered attractive because they are believed to:
- provide a more convenient service than public transport (or an alternative for areas without such provisions);
- reduce driver fatigue (MAIF, 2009), which can then enhance productivity, and;
- improve social interaction (Agatz et al., 2012).

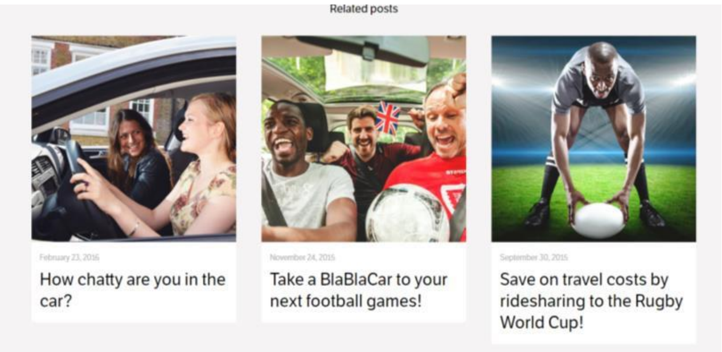
According to a recent paper by Delhomme and Gheorghiu (2016), conventional vehicle carpooling/sharing has successfully achieved many of the above aspirations (see also Ballet and Clavell, 2007). In terms of social-psychological determinants, a number of factors are likely to work together to determine users' willingness to engage in car and ride-sharing schemes, ideally, in exchange for utilising their own vehicle. These include the nature of the trip itself, such as its purpose, the length of the journey, the time of day (Chowdhury and Ceder, 2016; Malodia and Singla, 2016), the make and model of the vehicle (Kawgan-Kagan, 2015), as well as demographic determinants such as users' age, gender, socio-economic status (Vanoutrive et al., 2012) and personality (Roy, 2016).

Regarding demographics, in particular, studies show rather mixed findings. For instance, Kuhnimhof, Chlond, and von der Ruhren, (2006) found that when it comes to trips other than commuting, women are more likely to use these services, than men. Likewise, a recent survey of 1 207 drivers in France (52% of whom had carpooled), reports that women with children, who were also eco-conscious and had a positive view of public transport were the most likely demographic to use this kind of scheme (Delhomme and Gheorghiu, 2016). On the other hand, looking at e-car-sharing subscribers, Kawgan-Kagan (2015) reports this group to be over represented by men. Yet, she argues that women are likely to benefit from car and ride-sharing schemes, since this demographic normally has a more complex and varied mobility pattern: taking many shorter trips in the day to address a number of different personal and family-related errands. Organisations and policy makers are therefore encouraged to consider the needs of this demographic, when assessing methods for enhancing car-sharing uptake.

Using a Stated Preference web survey, Malodi and Singla (2016) confirm that, for conventional vehicles, two main factors affect consumers' desire for carpooling: time and cost. In terms of time, the authors considered both comfort and convenience in their analysis, arguing that aspects such as (i) the time it takes to reach the carpooling facility (ii) any waiting time at the pickup point, and (iii) the time used for picking up all other car poolers will all have an effect on the decision to use such facilities. In terms of consumers' impressions of costs associated with carpooling schemes, Malodia and Singla (2016) propose that increased use will be achieved by suitable promotional campaigns, which, for example, highlight the likely cost savings associated with such schemes. Furthermore, since the attraction associated with privately owned vehicles includes factors such as the provision of privacy (Gardner and Abraham, 2007), convenience, and comfort, not only allowing more freedom of movement (anytime/anywhere), but also affording more in terms of (driving) pleasure and higher social status (Beirao, and Sarsfield- Cabral, 2007), promotional campaigns should also consider what benefits the user will gain from ride-sharing, when encouraged to surrender their own vehicle, in favour of such services.

The use of suitable and targeted campaigns is also relevant when attempting to increase consumers' uptake of shared AVs. This uptake is also likely to be influenced by the ever-increasing availability of mobile apps, which are starting to provide consumers with Mobility as a Service (MaaS), where Intelligent Transport Systems (ITS) will create a tailor-made travel service for consumers (see http://maas-alliance.eu/). Furthermore, as additional social networking and crowd sourcing capabilities are added to such apps (e.g. see waze.appurse.com), consumers can potentially assist one another, transport suppliers/planners and app developers alike, to understand how the combination of available transport services are likely to influence factors such as travel time and cost. In addition, users can obtain information about the likely fuel cost of a journey, choose their preferred route by opting for the shortest/fastest option, or by selecting their favored type of road. Crowd sourcing will even allow scenery-based route selection, the attraction of which will have been be voted by others. Finally, for ride-sharing opportunities, users can choose like-minded companions, by joining social networking apps (see www.blablacar.co.uk, and Figure 1).

Figure 1. **Use of social networking facilities to enhance ride-sharing experiences**



February 23, 2016

How chatty are you in the car?

November 24, 2015

Take a BlaBlaCar to your next football games!

September 30, 2015

Save on travel costs by ridesharing to the Rugby World Cup!

Source: blablacar.co.uk

Users' desire to engage with AVs – web-based studies

In the past four to five years, a large number of studies have used on-line surveys and focus groups to understand public opinion and perception of AVs (J.D. Power, 2012; Casley et al. KPMG, 2013; Vallet, 2014; Schoettle and Sivak, 2014; 2016, Underwood, 2014; AAA foundation, 2016; Bansall et al., 2016). However, the focus here has been on understanding how much users are willing to pay for such technology, which in most cases is related to the users' own vehicle, with little investigation of their willingness to utilise public versions of such vehicles, in a ride-sharing setting. Overall, results illustrate a relatively cautious attitude from respondents, with some concern about reduced safety, mixed responses regarding willingness to pay for extra features, and questions about the legal/liability aspects of AVs. The surveys also do not show a clear pattern when assessing age and gender differences. For instance, Schoettle and Sivak (2015) report higher levels of willingness to pay for their older (>60 year- olds) and younger (21-34 year-olds) participants, whereas a 2014 survey by Seapine Software (2014) found a large proportion of these two age groups did not trust AVs (84% of 18–34 year-olds and 93% of 65 year olds).

In their most recent survey of individuals' preferences for vehicle automation, Schoettle and Sivak (2016) report that acceptance of vehicle automation decreases as the level of automation increases. Summarising the responses of 618 licenced US drivers, the authors found that only 15.5% favoured a completely self-driving car, with 38.7% accepting a partially automated car and 45.8% preferring to rely on manual driving. In addition, 94.5% of these drivers preferred to have access to a steering wheel or pedals, presumably allowing them to intervene in case of an emergency. The authors report this general pattern of responses to be similar to those conducted on a larger group of participants from across the US, UK and Australia, who took part in a similar survey in 2014. This similarity in results, obtained over the two year time gap, is perhaps a little surprising, especially considering the higher level of development/interest in (and coverage of) this type of vehicle between 2014 and 2016.

A similarly cautious response, regarding the contribution of AVs, is provided by results of a recent AAA survey (2016), which found that 75% of Americans would be "afraid to allow an autonomous vehicle to drive itself with them in it", with female respondents, in particular, expressing the most concern (81%). However, it is interesting to note that the respondents were generally more likely to trust systems that have already been in operation for some time, such as Adaptive Cruise Control (47%) or lane departure warning and lane keep assist (52%). This hands-on experience with systems is therefore an important factor in influencing results.

Unfortunately, however, a major shortcoming of most such large-scale surveys is that, due to the lack of wide-scale deployment and use of AVs by the general public, they cannot provide survey respondents with an accurate overview of the capabilities and limitations of the new technologies in question. It is also difficult for the surveys to capture an accurate understanding of users' actual use and impression of these vehicles. Results are therefore likely to be influenced by the interviewer's descriptions, or rely on respondents' impressions, which are, for example, shaped by promotional videos. As outlined in the next section, user trust and acceptance of new technologies is greatly influenced by their actual interaction and hands on experience with such systems, which casts some doubts on the true value of the results from the large-scale surveys outlined above.

Before summarising results from the small number of studies which have investigated consumers' views of shared AVs in recently completed projects, the next section will provide a short overview of the factors that are thought to influence users' trust and acceptance of AVs, which should ultimately lead to their use and uptake.

Factors influencing trust and acceptance of AVs

Distinguishing between acceptance and acceptability

If AVs are to have a real impact on shaping future transport, user trust and acceptance of these systems must be high. The terms acceptance and acceptability are often used interchangeably, and there is currently little consensus amongst researchers with regards to their definition and how the concepts should be measured (Regan et al., 2006; Vlassenroot, 2006). However, it is recognised that these constructs play an important role in understanding users' behaviour and interaction with the system.

Schade and Schlag (2003) differentiate between the concepts of acceptance and acceptability based on the dimension of time, suggesting that acceptability is a prospective judgement about a measure or system without the actual need to have had experience or exposure to it. Acceptability is therefore synonymous with a user's attitude towards the system. On the other hand, acceptance is a post- hoc concept and generally measured after exposure, whereby users can express their support, either via their attitudes or by demonstrating a behavioural response. Separating the constructs in this way is useful, as it allows researchers to take a diagnostic approach – therefore not only evaluating what features could be improved (via acceptability), but also establishing the real-time/post-hoc impact of a system in the field (acceptance). This distinction also recognises that acceptability may not lead to acceptance, or that acceptance is not necessarily indicative of acceptability. Clearly, AV developers need to consider both the acceptability of shared systems, in order to maximise stakeholder buy-in, prior to their implementation, along with considering user acceptance of the systems after implementation. Indeed, Najm et al. (2006) suggest that "driver acceptance is the precondition that will permit new automotive technologies to achieve their forecasted benefit levels".

Use of social-psychological models to study user acceptance of AVs

To date, two social-psychological frameworks have been used to investigate user acceptance of information technology – the Technology Acceptance Model (TAM; Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003). UTAUT is an expanded version of the TAM and posits that the degree to which automated systems are accepted and ultimately used will be impacted by seven main variables (Venkatesh, Thong, and Xu, 2012), see Table 1 for an example of how these were adapted for a recent study, investigating the value of the model for assessing the acceptance of AVs.

Table 1. **UTAUT Construct Definitions used by Madigan et al.**

UTAUT Construct	Definition
Performance Expectancy	The degree to which using a system will provide benefits to consumers in their travel activities
Effort Expectancy	The degree of ease associated with system use
Hedonic Motivation	The fun or pleasure derived from using the system
Facilitating Conditions	Consumers' perceptions of the resources and support available to use the system
Social Influence	The extent to which consumers perceive that important others (e.g. family and friends) would use the system
Price	Value for Money
value	The extent to which an individual believes a behaviour to be automatic
Habit	

Source: Adapted from Vankatesh et al., (2012)

Numerous studies have investigated the impact of one or more of these variables on users' acceptance of vehicle automation (e.g. Park, Junghwan, Changi, and Seongcheol, 2013; Osswald Wurhöfer, Trosterer, Beck and Tscheligi, 2012; Zmud, Sener and Wagner, 2016). However, to date, only one study has investigated acceptance of shared AVs with people who have actually experienced these vehicles. Using a questionnaire study, conducted as part of the CityMobil2 trials in three European cities (Lausanne - Switzerland, La Rochelle-France, and Trikala Greece), Madigan et al. (2016, submitted) used an adapted version of the UTAUT to investigate user acceptance of Automated Road Transport Systems (ARTS), the term used for the AVs used in this project (substituting "the system" with ARTS, where appropriate - see Figure 2).

These authors found that Hedonic Motivation or respondents' enjoyment of AV use, had a large impact on their desire to use these vehicles again. However, since 79% of survey respondents had used the AV less than five times, this response is likely linked to the novelty value associated with the facility and an assessment of the longer term impression of the AV is clearly warranted. AV performance, the resources provided to support their use, and the social norms surrounding the AVs also influenced users' decisions about whether or not they would use the AVs again in the future.

Figure 2. The EasyMile (left) and ROBOSOFT (right) vehicles used in the CityMobil2 project

Source: La Rochelle photo courtesy of © Frédéric Le Lan, Communauté d'Agglomération de La Rochelle.

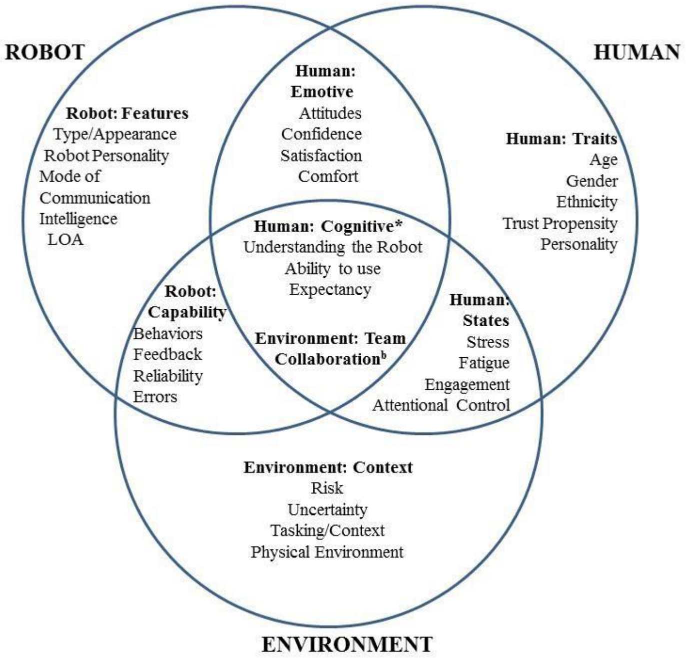
These results have a number of design implications for shared AVs, since it is likely that, as people become more familiar with AVs, the excitement and enjoyment of using them may decrease. Therefore, developers need to consider the use of different approach to maintain this enjoyment, such as ensuring user comfort, or promoting the use of AVs for working or social networking activities (Nordhoff, Van Arem, and Happee, 2016a). Designers of AVs also need to ensure that these systems perform to a high level and are reliable, along with optimising their connectivity with other transport services (Sessa et al., 2015). Finally, providing the correct infrastructure and increasing public engagement and awareness of the vehicle's capabilities is also likely to increase the acceptance of these AVs.

From acceptance to trust

It is important to note that the UTAUT model considers users' adoption decisions as a rational, goal- directed behaviour that results from controlled and deliberate reasoning (Venkatesh et al., 2003). However, what is currently lacking in this context is the effect of unconscious psychological processes that are beyond the direct control of users. For example, one acceptance factor that meets these conditions is user trust, which has a strong influence on the reliance, acceptance and adoption of innovative technologies (Nordhoff, Kyriakidis, Van Arem, Ruhrort, Graff, and Happee, 2016c, see also Choi and Ji, 2015). Trust in automation refers to the user's belief in the reliability or ability of the automated system (e.g. Parasuraman, Sheridan, and Wickens, 2008). In studies considering trust during human robot interaction (HRI), a multitude of factors are considered to be responsible for establishing the user's trust in the robot's capabilities, and some or all of these will ultimately ascertain whether or not the robot/system is used and accepted. A number of models have been proposed in this context, and although some are beginning to be linked directly to AVs, many were originally developed for other forms of automated systems and robots.

According to the Three Factor Descriptive Model of Human Robot Trust (see Hancock et al., 2011; Schaefer et al., 2016), environmental, human and robot related factors all influence users' trust in a system, with the three elements also influencing each other, as shown in Figure 3.

Figure 3. **Venn diagram showing the interdependent nature of trust across the three factors of trust**



a The items listed as cognitive factors include additional antecedents of trust: ease of learning, prior experiences, self-efficacy, workload, expertise, familiarity, and proximity. **b** The antecedents of trust with the team collaboration category include role interdependence, team composition, mental models, cultural and societal impact, and in-group membership.

Source: Schaefer et al., 2016

Hoff and Bashir (2015), build on this model to provide a number of recommendations about maximising appropriate trust in automated systems. They suggest that usability of a system will affect how much it is trusted. Operators will generally trust an automated system if it behaves in the manner they expect. However, if they experience unanticipated actions, there is a rapid drop in trust that often leads to disuse (Schaefer et al., 2014). Therefore, designers of shared AVs need to consider the expectations of potential users and ensure that their vehicles can meet these expectations.

Numerous studies have shown the influence of cultural, gender and age differences in shaping consumers' willingness to trust and use automated vehicles (Kyriakidis et al., 2015; Schaefer et al., 2014), although again, these are not necessarily based on hands-on experience with shared-riding AVs. Nevertheless, in order to accommodate for diversity in cultures and demographics, designers of AVs should consider implementing features that can be adapted to the needs of target user groups (Hoff and Bashir, 2015). This point is also highlighted by Grush et al. (2016), who suggest that studies considering the successful deployment of AVs should focus on understanding consumer preferences when designing the correct programmes, or offering the appropriate subsidies, since a "one size fits all" approach to public transport is regularly unsuccessful.

Appropriate trust in AVs is also likely to be facilitated by the provision of accurate, ongoing, and up- to-date feedback on both the reliability of automation, and any situational factors such as traffic conditions or weather, which might affect its performance (Seppelt and Lee, 2007; Hoff and Bashir, 2015). However, it is important to reach an appropriate balance between providing timely and helpful updates, versus overloading users with too much information. For example, experimental research by Lees and Lee (2007) found that while false alarms decreased trust in a vehicle collision warning system, unnecessary alarms i.e. instances where the automated device indicated a hazardous event which the human driver did not deem to be hazardous, actually increased trust. Finally, a recent paper by Ekman et al. (2016) suggests that understanding that “trust formation is a dynamic process that starts long before a user’s first contact with the system, and continues long thereafter” and, of course, user interaction with the system over time is also likely to affect this trust.

Appearance and communication style are also likely to have an impact on the development of user trust. If an automated aid or machine is perceived to be aesthetically compatible with its function, it is more likely to be used (Goetz et al., 2003). Research also suggests that the anthropomorphism, or human-like characteristics, of an interface can be a significant variable (e.g. de Visser et al., 2012), and that trust in automated systems can be increased by making the system more human-like. However, there have been mixed findings regarding the effects of appearance on trust in automated vehicles. Research by Weinstock, Oron-Gilad, and Parmet (2012) found that system aesthetics did not necessarily affect trust in an imperfect in-vehicle navigation system, and that the performance of the system was a more important variable. A more recent study by Lee et al. (2015) compared participants’ evaluations of perceived intelligence, perceived safety, and trust in an automated driving system (a remote-control car) based on whether the vehicle appeared to be controlled by a humanoid robot or by an iPhone. They found that the combination of a human-like appearance, with high autonomy i.e. the ability to make driving decisions, led to higher ratings of perceived safety and trust. However, since there was no real risk associated with the remote- control car, it is unclear whether similar results would emerge in interactions with real-world vehicles. Once again, there has been little actual research into the effects of vehicle appearance on users’ trust or acceptance of shared AVs. However, a small focus group study, conducted as part of the CityMobil2 trials in La Rochelle (see Dziennus et al, submitted), found that participants liked the high visibility offered by the vehicle’s large windows, but were confused about its direction of travel, which was not easy to comprehend, due to the absence of a driver and lack of any traditional vehicle controls.

Indeed, it is worth noting that many of the current ride-sharing versions of AVs do not include a steering wheel, or gas and brake pedals. This changes the role of the person on-board the vehicle from an active driver to a passive passenger. For these vehicles, establishing user trust is crucial, to prevent the abuse or misuse of the AV (Schaefer and Straub, 2016). In a recent study examining the effect of driver controls on driver behavior and trust, Schaefer and Straub (2016) asked 18 drivers to interact with two versions of a simulated driverless vehicle: one with and the other without traditional vehicle controls. A red (disengage automation) and green (reengage automation) button were available for both set ups. The authors found that drivers were less likely to press the red button when the vehicle lacked traditional controllers, allowing the system to complete its task.

A number of questions remain here, such as whether this lack of intervention was due to the colour of the disengage button, which is universally associated with danger/emergency situations, and may have therefore prevented user response. In addition, understanding how users of different age and ability interact in such circumstances, and whether a need to intervene is influenced by the expected (versus unexpected) behaviour of the vehicle, are some of the factors that require further investigation. Nevertheless, results from this small-scale study suggests that drivers’ desire to intervene with the actions of a successfully operating automated system is reduced in such circumstances, which is useful for fully operational, faultless and capable systems, since it prevents unnecessary human intervention and reduces the likelihood of new and unforeseen errors.

As we progress towards the deployment of shared AVs, some form of communication and interaction mechanism may be required to positively relate to their acceptance and use. These control mechanisms can take the form of a safety button inside the vehicle that can be pressed by passengers to stop it in case of an emergency or unforeseen circumstances. The connection of the vehicle to a hotline that provides (technical) information may also increase use and acceptance, in case of system breakdown (Nordhoff et al., 2016b).

Finally, in addition to improving the technical capabilities of AVs, the introduction of AVs should be associated with the simultaneous management of individual expectations. This is important because research has indicated that long-term acceptance may be seriously hampered if a priori capabilities are based on unrealistic, idealised expectations, before individuals actually experience these vehicles (Beggiato and Krems, 2013). Therefore, we propose that the creation of more realistic expectations can be achieved by exposing the public to the technology at a very early stage and in an iterative manner, using small scale demonstrations under limited conditions, allowing individuals to gradually gain familiarity with these vehicles and learn about their technological capabilities and limitations (Seppelt and Lee, 2007).

Real-world studies on user acceptance of ride-sharing AVs

Using an online survey, supplemented by a series of telephone interviews, Piao et al. (2016) report on the views of 425 respondents living and working around the route of the CityMobil2 ARTS vehicles in La Rochelle (with 87% of the sample reported to be aware of the vehicles' presence in the city). The sample of 18-65 year olds (53.6% female) was asked to compare automated buses, cars and taxis to conventional versions of such vehicles. Results showed that the majority of respondents were positive about the automated vehicles, if they were offered at a lower price (likely to arise due to the absence of a paid driver), provided more space (due to the absence of vehicle controls) and were more readily available upon request, when compared to conventional vehicles. However, safety and security were reported as a problem for automated vehicles, with night- time services being of particular concern.

The City Automated Transport System (CATS) project, which tested a publically shared driverless electric vehicle (Navya Shuttle) on the EPFL campus in Switzerland, provides a comprehensive summary of a questionnaire completed by 181 users (66% male, 70% aged between 20 and 50 years). The study suggest that respondents were willing to pay about the same price for this service as a conventional vehicle, and thought the vehicle was user-friendly (92%) aesthetic (81%) and functional (80%). However, due to gradual damage to the road infrastructure, caused by the weather and also inappropriate speed management on slopes, only 14% of participants found the quality of the ride to be "excellent". Respondents also found the vehicle to be easy or very easy to use (92%) safe or very safe (91%) with 82% reporting the size and speed of the vehicle to be suitable for the EPFL campus (12 km/h), although opinions were divided on speed, which is slightly faster than walking pace. Finally, lack of seating and window panes were considered a weakness of the vehicles.

User willingness to share a small unattended vehicle with strangers

The acceptance and uptake of AVs is likely to be influenced by the extent to which users like to share space with other people in a public transport setting. This may also be further affected by the presence (or not) of a vehicle operator, with users likely to be more apprehensive of sharing the vehicle with others, in the absence of an operator, although remote observations/CCTV will likely help to (at least partly) alleviate this sense of unease. According to Hall's proxemics theory (1966), strangers are forced into an intimate social distance in a public transport situation, which often causes psychological or social discomfort. Clearly, the level of perceived discomfort will increase with passenger density, because it is likely to create closer interpersonal space between passengers. Lack of familiarity with others in the vehicle is also likely to influence this level of discomfort, as corroborated by a recent survey by Bansal et al. (2016), who sought the views of 347 Austinites, on factors which influenced their car- and ride-sharing decisions. The authors report that for rides taking place during day time hours and for short durations, 51% of respondents stated that they were comfortable in sharing a ride with a stranger, with 53% reporting that they would share with a friend of one of their Facebook friends (including ones they had never met). However, the highest figure of 90.8% was reported for sharing of rides with regular friends and family members. This survey also reports that full-time male workers living in urban areas were the most likely to use shared automated vehicles, provided costs were in line with current pricing schemes for shared vehicles. This finding is in contrast to the research of Delhomme and Gheorghiu (2016) in France, which found a higher likelihood of females with children using conventional forms of car-sharing, showing that the lack of a human operator may lead to differences in who chooses to use these systems.

When investigating the views and well-being of seated passengers in a public transport setting, regarding a train journey between New Jersey and Manhattan, Evans and Wener (2007) report that stress in a crowded carriage is based on the violation of personal space or perceived privacy, rather than the overall carriage density. This explains why the central seat of a three-seat row, for example in busses and train carriages, is the last to be occupied, leading the authors to recommend the inclusion of 'territorial props' such as armrests and tables to enhance enjoyment of the journey. Hall (1966) also highlights a number of strategies adopted by passengers in a public transport setting when their personal space is invaded by strangers. These include avoiding eye contact and touch, as well as tensing muscles to remain immobile and avoid intimacy in a socially awkward situation. This basic psychological need for personal space may also explain why the privately owned car is still the most common mode of transport in many places in the world, even in less car-dependent places which have more sustainable and environmentally-friendly travel (Olafsson, Nielsen, and Carstensen, 2016). Therefore, since many of the currently developed initial prototypes of shared AVs in a public transport setting provide seating capacities for around 8 -10 passengers, with little consideration of enhancing such personal space, they are likely to exacerbate feelings of tension and stress for users, especially during longer journeys. Research will therefore benefit from taking the design requirements of AVs into account, to ensure large-scale acceptance and uptake of these vehicles. In addition, as highlighted in a recent panel discussion at the International Research Council on the Biomechanics of Injury (2016), currently deployed examples of shared AVs do not include any of the standard passive safety features incorporated in conventional vehicles. This absence of airbags, seatbelts and strong body structures in AVs, is likely to reduce their safety in case of a collision and will likely reduce costumer acceptance, unless addressed in future models.

Realistic opportunities to serve mobility-impaired users

One group who are consistently identified as benefiting from the introduction of automated vehicles are mobility-impaired groups such as the elderly or those with disabilities. Investigating the opportunities of AVs to serve mobility-impaired users involves the differentiation between SAE level 4 and SAE level 5 automation, with each having different effects on the extent to which individuals find AVs acceptable and useful, and the democratisation of mobility in general. The potentials of AVs to provide door-to-door transport everywhere and anytime can only be fully unleashed with SAE level 5 automation, whilst the mobility options at SAE level 4 automation remain limited as impaired individuals need to bridge the so-called first or last mile themselves (Nordhoff, Kyriakidis, Van Arem, Ruhrort, Graff, and Happee, 2016b).

Due to the removal of steering wheels and pedals in AVs, they have generally been considered as an attractive mobility option for mobility-impaired users, such as children, seniors or people with disabilities. License holding, and the availability of a car drop significantly at the age of 75, mainly due to health effects, which increases the need of such users to use driverless vehicles as they constitute a low-cost, convenient and flexible age-appropriate mobility solution (Krueger et al., 2016). In addition, individuals who have been previously excluded from riding a car or taking public transport may be those who suffer more from age- related disabilities, such as visual, physical or cognitive disabilities (Anderson, Kalra, Stanley, Sorensen, Samaras, and Oluwota, 2014). Pristavec (2016) shows that the facilitation of ride-giving, and developing flexible transportation options, may enhance social participation among older adults who cease, or begin ceasing, to drive. However, the regain in mobility and social participation will only be achieved if AVs are accepted by these groups, and current research is still ambiguous on the commonly hypothesized correlations between age or impairment and the willingness to accept and use AVs. For example, Krueger et al. (2016) found that respondents aged between 65 and 84 are not more likely than respondents between 24 and 29 years to use shared automated vehicles.

When considering privately owned use of AVs, Payre et al. (2014) found that as age increases, the intention to use automated cars decreases. The same difference was observed by Schoettle and Sivak (2014) who found that younger people were more interested in using self-driving technology than older people. Further support for age differences in attitudes towards automated cars were found by Kyriakidis et al. (2015) and Bansal et al. (2016), who showed that, compared to older people, younger people were willing to pay more for these vehicles (Hohenberger et al., 2016). One possible explanation may be the lower level of trust in self-driving vehicle technology among older cohorts, which drops with age (see: 56% of Gen Y (1977-1994) and 55% of Gen Z (1995-2000) stated that they trusted self-driving technology, compared to 41% of Gen X (1965-1976), 23% of Baby Boomers (1946-1964) and 18% of Pre-Boomers (born before 1946). Further, the proportion of respondents indicating that they would not trust self-driving vehicle technology was 18%, 11%, 27%, 39% and 40% for the generational cohorts respectively (J.D. Power, 2016).

However, a meta-analysis conducted by Schaefer et al. (2014) contradicts these studies, finding that older adults showed a higher level of trust in automation than younger adults. Similarly, an online survey investigation of a group of older Floridian adults aged over 55, found that attitudes towards, and acceptance of, AVs was higher for those reporting ease with higher levels of technology (Souders and

Charness, 2016). This group also reported higher interest in different models of AV ownership, and were more likely to report that the introduction of autonomous vehicles would be beneficial in terms of safety enhancements, less traffic congestion or enhanced mobility for those unable to drive (Souders and Charness, 2016). As highlighted earlier, one reason for this apparent anomaly in findings may well be the lack of data from real-world studies in this context.

The UTAUT model, discussed earlier, suggests that individuals' usage of a system is determined by facilitating conditions, indicating that an advanced technical infrastructure could support the acceptance and use of AVs among older users. AVs should be easy to use, non-intrusive and easy to access by people with disabilities, even for those who do not own a personal electronic device. Access to an organisational and technical infrastructure may include, but is not restricted to, a smartphone and the corresponding smartphone app, providing information on the real-time position of the AV, its near-future trajectory and enabling booking and payment for AV use. The provision of this technical infrastructure to facilitate the acceptance and use of AVs should form part of a systemic and holistic approach to encourage the use of AVs among age- or physically/visually impaired people. This systemic approach of enabling acceptance and use of AVs among people who have been previously excluded from driving a car or using public transport must take into account both the features inside and outside of the AV. For instance, a wheelchair ramp may provide physical access to the vehicle, while a technical hotline ensures the digital connectivity between vehicle and control units outside the vehicle that provide assistance in the case of (technical) questions. This can be particularly beneficial for those users without personal mobile devices. Other elements outside the vehicle which may increase connectivity may include sign posts, bulletin boards, and benches that are connected to the digital information space, facilitating implicit or explicit interaction in public spaces (Kötteritzsch et al., 2016). One example would be responsive street furniture that enables passengers to submit their inquiries and receive information regarding reservation and cost options for the next available shared AV.

Interactions of AVs with pedestrians and bicyclists

The challenges in the development of AVs do not stop inside the vehicle. There is also a need to consider the interaction of automated vehicles with other road users, particularly in situations such as those explored by the CityMobil2 (www.citymobil2.eu) and the Lutz Pathfinder (see https://en.wikipedia.org/wiki/LUTZ_Pathfinder) projects, where it is anticipated that AVs will operate in a shared space with vulnerable road users such as pedestrians and cyclists.

Currently, pedestrians and cyclists use various implicit and explicit cues to understand a vehicles' intended behaviours on the road. Some of these cues involve explicit two-way communication such as eye- contact, physical gestures and the use of flashing lights (Sucha, 2014). Other vehicle-centric cues such as velocity, distance, trajectory, and speed limit are also used to aid pedestrians in their decision-making when it comes to crossing the road (Sucha, 2014; Schneemann and Gohl, 2016). Research has shown that vehicle speed, in particular, can have an impact on how pedestrians make their decisions. In faster speed zones, pedestrians tend to use the behaviour of an oncoming vehicle to judge whether it is safe to cross the road, whereas in slower speed zones they tend to rely more on eye-contact with the driver (Schneemann and Gohl, 2016).

Although, we have some understanding of how pedestrians interpret the actions of vehicles with drivers, one of the huge challenges for the roll-out of AVs is how to replicate these implicit and explicit communication strategies in the absence of person-to-person communication. Vehicle manufacturers have only recently turned their attention to this issue. In 2015, Google secured a patent for technology to communicate with pedestrians which proposes the use of electronically-based mechanisms and messages to mimic human behaviour, including the use of robotic hands and eyes, along with written messages or moving graphics designed to let pedestrians know the car's intentions (Urmson et al., 2015). Mercedes have also developed a concept car which includes a laser to project a crosswalk in front of the vehicle when it stops, in order to tell a pedestrian it sees them and is expecting them to cross (Kerferbock and Riener, 2015). Similar efforts are in place by other vehicle manufacturers and tier 1 suppliers. However, despite these novel suggestions, to date, there have been very few experimental studies examining user acceptance and understanding of these communication techniques.

A number of projects at Chalmers University have made use of the Wizard of Oz (WOZ) technique to examine pedestrians' interactions with a "fake" driver. The WOZ technique is based on the idea of using a human operator to simulate a fully working technical system, and users are generally told that they are interacting with an automated system. Habibovic and colleagues (Habibovic et al., 2016, Langström and Lundgren, 2015) set up a WOZ experiment by placing a dummy steering wheel on the passenger side of a vehicle, and hiding the real steering wheel from sight. A "fake" driver in the passenger seat seemingly drove the vehicle or engaged in distracting activities such as looking at their phone or a newspaper. Experimental and interview results showed that pedestrians were less willing to cross in front of the vehicle when the driver appeared distracted, and they expressed discomfort when there was nobody sitting in the driver seat. They did not suspect that the vehicle was automated or driven by WOZ, suggesting that until people have time to get used to automated vehicles, they should be perhaps be designed to look different from regular cars.

Langström and Lundgren (2015) and Clamann, Aubert, and Cummings (2017) have explored a number of potential communication techniques between automated vehicles and pedestrians, with mixed results emerging. Langström and Lundgren (2015) found that after training, pedestrians were able to understand the signals conveyed by an LED strip located at the top of a vehicle windscreen, and used these to illustrate appropriate crossing decisions. However, it is unlikely that the pattern of LED lights presented in this study will provide an intuitive message to an untrained/unfamiliar pedestrian. Therefore, some effort is clearly required in this area, to understand the communication needs between pedestrians and AVs, and as manufacturers begin to propose new communication methods, the introduction of new, globally acceptable, standards will need to be considered.

In a study assessing pedestrians' interactions with three vehicle-to-pedestrian messages (see Figure 4), Clamann, et al. (2017) investigated crossing behaviour at different types of road crossing. Each message was placed on an approaching 'driverless' van, and pedestrians were asked to indicate when it was safe to cross. Results showed that there were no significant effects on crossing time, based on the type of display. The authors use this data to suggest that pedestrians are more likely to base their crossing decisions on existing strategies, such as gap acceptance and vehicle trajectory, indicating that display types may be less important than assumed.

Figure 4. **Vehicle intention displays used in Clamann et al. (2017)**

In addition, this study found age and gender related differences, with younger participants illustrating riskier crossing decisions, and males showing quicker decisions than females. This study, therefore, suggests that different strategies may be required for communicating with different demographic groups.

The CityMobil2 trials, outlined above, also sought to evaluate how pedestrians and other road users might interact with low speed shared automated vehicles. A questionnaire study, by Merat et al. (submitted), showed that pedestrians assumed they had priority of movement over the automated vehicles when operating in a shared space, but that the AV was assumed to have priority, if moving through a clearly demarcated lane. Pedestrians also reported higher ratings of perceived safety when road markings were present. In terms of how AVs' behaviour should be communicated, results showed that participants were particularly keen to know they had been detected and wished to receive information about the turning, starting and stopping of the ARTS, but that external information regarding the speed of the ARTS was not deemed important. This supports the finding of Clamann et al. (2017) that pedestrians are able to make use of vehicle-centric cues to appreciate vehicle speed. On the whole, participants from this study preferred the use of lights to provide information about whether the vehicle was turning or stopping, and sounds to indicate whether it was going to start moving and whether they had been detected. However, it should be noted that there were differences in preference across the three locations examined (Lausanne in Switzerland, La Rochelle in France, and Trikala in Greece) suggesting there may be some cultural differences in how the communication tools used by these vehicles are perceived. Results from this study suggest that other road users would like to receive some form of information from the AVs when the space is shared between these actors, and that knowing they have been detected by the AV is the most important message to pedestrians and cyclists.

Summary and conclusions

As the implementation of more advanced, sensors, radars and localization/navigation technologies in vehicles increases, there is potential for the mass-deployment of a new form of publicly available, electrically operated, 'driverless' vehicle for the urban environment, which can be adopted for sole or shared use. Such SAE Level 4 vehicles (striving towards Level 5) have the potential to provide first mile/last mile transport, and, if designed with the needs of the user in mind, can greatly enhance traffic flow and management in cities, whilst reducing transport-related emissions. By denying access to privately owned vehicles in busy city centres, yet allowing easily accessible transport within the city, which complements walking and cycling facilities, these vehicles also have the potential to remove the need for parking spaces and are considered a solution for increasing green spaces in congested urban environments. Their successful deployment is also likely to contribute to improved health and social well-being of citizens and enhance enjoyment of the local environment. This type of AV may also provide on- demand access to more remote areas, not easily served by traditional public transport, and can potentially be beneficial to mobility-impaired individuals or those who have ceased (or have never learned) to drive. It can be argued that, until recently, much of the effort dedicated to the implementation of such vehicles has focussed on improving their operational and technical aspects. However, it is now time to consider the policy and behavioural factors that will allow successful deployment and user/societal uptake.

This paper provides an overview of the social-psychological factors that are likely to influence the trust and acceptance of AVs, starting with a short summary of the factors that have influenced users' engagement in ride-sharing for conventional vehicles. It is argued that that, since there is currently a severe lack of data on (different) users' actual hands-on and day to day experience with fully functioning, trustworthy and infallible AVs, any recommendations must rely on results from a limited number of studies which have conducted small-scale demonstrations of these vehicles (mostly in Europe) . In addition, many of our assumptions in this context must still be based on what we know about users' interactions with automation in other domains, together with results from large-scale on-line surveys, which seek user opinion on these systems, which have not actually been fully developed, tested or implemented. Nevertheless, based on this short overview, it can be assumed that for such low speed shared urban AVs to successfully replace the developed world's dependence on (and love of) the privately owned motor vehicle, they must overcome a number of fundamental barriers, and perhaps for the first time, should be designed for, and by, the user.

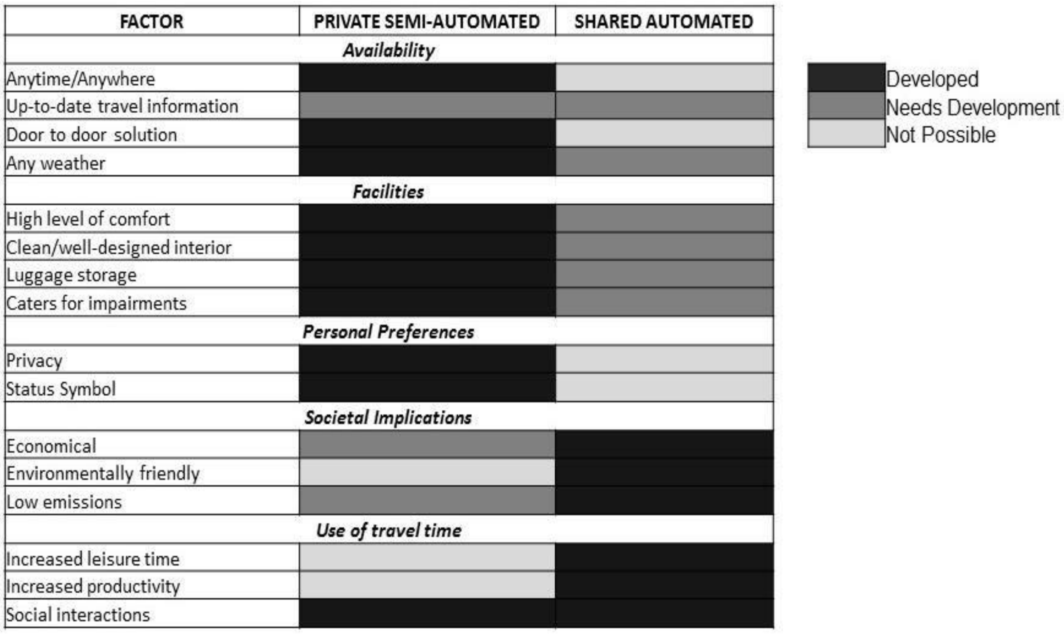
The question at the moment is whether individuals will prefer to continue investing resources in their privately owned motor vehicle, or be willing to take advantage of the services offered by automated ride- sharing services. As outlined above, the time and cost associated with each service play an important role in this decision-making process, and the influence of user demographics and city infrastructure cannot be ignored.

In the coming years, the consumer is faced with two potential (possibly complimentary) options: investing in a (i) privately owned, semi-automated (level 2/3) vehicle which strives to provide level 4 capability, and/or investing in/paying for the use of a (ii) highly-automated level 4 vehicle, which may also be shared with others. We argue that apart from reducing energy use and emissions, the availability of options for the former type of vehicle are currently superior to shared AVs. For the latter to be accepted and used, it will need to be:

- reliable and safe;
- available at any time;
- able go anywhere and everywhere, and;
- capable of operating in all weather conditions. The shared AV must also provide:
- a clean, comfortable and safe interior environment;
- enhanced privacy features;
- allow easy access for dependents (children, impaired and elderly) and their equipment (luggage, push chairs, wheelchairs).

Therefore, as outlined in Figure 5, the private semi-automated vehicle available today and in the near future, provides a level of convenience and comfort which is perhaps superior to the shared AV. Therefore, for shared AVs to be considered a serious alternative to privately owned vehicles, city authorities will need to work with manufacturers and suppliers to enable the development of some, if not all, of the features offered by privately owned vehicles.

Figure 5. **Overview of factors that influence consumer choice for private semi-automated and shared fully automated vehicles**



FACTOR	PRIVATE SEMI-AUTOMATED	SHARED AUTOMATED
Availability		
Anytime/Anywhere	■	□
Up-to-date travel information	▨	▨
Door to door solution	■	□
Any weather	■	▨
Facilities		
High level of comfort	■	▨
Clean/well-designed interior	■	▨
Luggage storage	■	▨
Caters for impairments	■	▨
Personal Preferences		
Privacy	■	□
Status Symbol	■	□
Societal Implications		
Economical	▨	■
Environmentally friendly	□	■
Low emissions	▨	■
Use of travel time		
Increased leisure time	□	■
Increased productivity	□	■
Social interactions	■	■

■ Developed

▨ Needs Development

□ Not Possible

The pace of technology improvement in this area, and the dedicated interest and investment by manufacturers and policy makers alike provides hope that such developments for shared AVs are possible. As social-networking and crowd-sourcing opportunities increase, travellers are likely to have a strong influence on shaping their own means of mobility, which can in turn be influenced by an individual’s subjective norm. With increasing congestion in cities, rising fuel costs, expensive and limited car parking facilities, citizens of the developed world may well appreciate the benefit of access to vehicles providing high levels of automation. For a time-poor and connected society, these vehicles are likely to allow engagement in other activities, increasing comfort, productivity and enjoyment. However, the ultimate success of ride-sharing AVs will only be achieved following an effective collaboration between manufacturers, local and central government, to provide citizens with the most suitable options for each specific environment.

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