RESPONSE TO THE INQUIRY INTO SOCIAL ISSUES RELATING TO LAND-BASED DRIVERLESS VEHICLES

Prepared by iMOVE CRC for the House of Representatives Standing Committee on Industry, Innovation, Science and Resources

Ian Christensen
Bid Lead, iMOVE CRC

Response to Inquiry into the social issues relating to land-based driverless vehicles in Australia

Introduction

Emerging transport technologies are permanently changing the way that we move people and goods in Australia and globally. Faster computers and better data already enable machines and systems to provide greater assistance to drivers and perform many routine tasks involved in the movement of goods. As the computers and data improve, more and more opportunities arise to take advantage of their speed and accuracy to reduce errors, reduce incidents, and save time and energy.

Driverless trains and trucks are already in operation in some mining environments and there are strong prospects for automation to be applied to more routine driving tasks. Many car and technology companies are already well progressed in the development of driverless vehicle prototypes and in some cases they already have vehicles on the road (eg Google, Tesla).

In spite of this progress, the concept of vehicles not needing a human driver remains somewhat futuristic for many people and the prospect of trusting one's life to a computer is not yet well accepted. In part this is because few people have had direct experience of driverless vehicles and the discussion in the global media has not always been balanced or helpful. As with many technical subjects, much of the nuance is lost in the shrill headlines and the public has only a modest grasp of the differences between connected, automated, autonomous and driverless vehicles.

iMOVE CRC bid

This submission has been made by the bid team for the iMOVE Co-operative Research Centre (CRC). The iMOVE bid is a proposal to the federal government's CRC program to establish a new CRC focussed on making better use of data to improve the mobility of our people and freight. The proposal consortium comprises forty six organisations that have collectively committed $55 million in cash and $124 million in-kind to a ten-year endeavour to:

- develop methods to manage traffic more efficiently
- leverage the ability of more automated vehicles to increase road capacity and reduce crashes, better co-ordinate our transport vehicles
- optimise logistics, and
- give commuters co-ordinated travel options that will reduce the peak demand for road space.

Twenty eight members of the consortium are 'end users' of emerging technologies and include large logistics companies, large and small technology companies, insurance companies, all the mainland road authorities, automobile associations, and departments of local, state and federal governments. This submission is made on behalf of the consortium, though several members will be making submissions of their own.

This submission draws on the experience and views of the iMOVE bid participants and on several published analyses of community attitudes to driverless vehicles. Two of the participant contributions and three of the published papers are provided as appendices to this submission.

What do we mean by driverless?

The Society of Automotive Engineers defines six levels of automation. Levels 0 - 2 relate to vehicles that require human monitoring to varying extents. Levels 3 – 5 relate to vehicles in which the vehicle itself performs some or all of the driving tasks, reflecting increasing levels of automation ultimately becoming completely independent of the vehicle occupants and thus “autonomous”. Driverless is a general term to describe vehicles which for at last part of its operations does not require human input.

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“Connectedness” is a different aspect that relates to how intensively the vehicle interacts with, and depends on data from other vehicles and roadside infrastructure. A vehicle can be autonomous or driverless without necessarily being connected. Such a car will detect and avoid objects (including other cars) - but not necessarily communicate with other vehicles and infrastructure. Many of the prospective benefits of driverless vehicles to our transport systems depend on them being “connected” electronically to the system and acting co-operatively with one another. Once the system is in place connectivity need not be limited to motor vehicles. The connected system would also enable other (more vulnerable) road users such as pedestrians and cyclists to be registered on the system and be automatically visible to connected vehicles and to traffic lights.

This submission covers issues associated with the introduction of any of these technologies and summarises what we see as the main positive and negative impacts. It offers commentary on several important issues and considers driverless vehicles within the Australian context. It concludes with some recommendations to address the identified issues.

Positive impacts of driverless vehicles

Public attitudes to driverless vehicles range from excitement to trepidation. In considering the “issues” associated with these new technologies we should not overlook the strong desire by the community to access the prospective benefits that the new technologies promise. The features most strongly sought by the community are:

- Safer roads

  The current toll of injury, damage and death from road incidents weighs heavily on the community and the frequency of incidents means nearly everyone in the community is impacted in one way or another. Studies of road incidents have concluded that human error is responsible for 80-90% of crashes (drink, tiredness, misjudgement, inattention etc.). Driverless vehicles offer a unique opportunity to almost eradicate these accidents and prevent the resultant devastation.

  Driverless vehicles also have the potential to keep our more vulnerable road users safe (cyclists and pedestrians). Other studies (Deloitte) show that safety is an attribute that is sought and expected by consumers from driverless and automated vehicles.

- Reduced costs
  The advent of autonomous vehicles is expected to create and support new modes of travel including, ride hailing (e.g. Uber, taxis), ride sharing, vehicle sharing, and mobility as a service. In all these cases the cost of the vehicle is spread over a large group of users and so costs per person and per ride are expected to fall. A significant reduction in road incidents, would be expected to lead to reduced insurance premiums.

- Reduced need for parking
  In the event that the vehicle is able to drive without any human monitoring, after it has delivered its 'first' passenger, it can return to base or be used to perform other tasks, rather than the driver having to find (often expensive) parking.

- Social inclusion
  Driverless vehicles will create more options for people who currently face mobility challenges such as the elderly and disabled or those that do not hold a licence. This will increase autonomy and reduce isolation for many. It may also allow greater levels of independent living.

- Job creation
  There will be a need for skilled people to develop, manage and support driverless vehicles. This is likely to result in more jobs being created than lost in the long run, however these jobs will likely be more highly skilled than those lost through this technological development (see community concerns).

- Better traffic flow. / reduced congestion
  When vehicles are connected and can communicate with infrastructure, such as traffic lights, substantial improvements in intersection management and traffic flow become possible. Vehicle to vehicle communications enable vehicles to co-operate automatically and improve traffic flow and throughput.

- Better use of time
  Another strong incentive for many (time poor) members of the community is the prospect of more effective use of time. Removing the need to focus on the driving task frees up the time in the vehicle to be used more productively for work, relaxation, or even sleep. This would reduce the time cost of travel, reduce the pressure to live close to the location of the work, and more generally support decentralisation. It would also increase people's geographic range of work opportunities.

  Not requiring a licensed driver might also offer families more flexibility as they try to juggle competing demands for getting each member from A to B.

- Environmental improvements
  Smoother and more stable traffic flows that are enabled by the interaction between connected vehicles and between vehicles and infrastructure require less stopping

and starting, and so generates lower fuel consumption, less pollution and lower carbon emissions.

- Better mobility options
  The prospect of highly automated vehicles also creates possibilities of better intermodal connectivity and may usher in new and better ways to utilise public transport. For instance driverless vehicles ordered through an app. on a mobile phone could provide feeder services into high volume, rapid transit, public transport systems. They could automatically coordinate with other transport systems to provide 'last mile' services to a much larger catchment than is currently possible.

Community concerns about driverless vehicles
All studies on the subject reveal ambivalence by the community towards driverless vehicles. Notwithstanding the perceived opportunities for benefit, there are also significant reservations, and unless these concerns can be addressed and resolved, adoption of the new technologies is likely to be constrained.

There are various ways to categorise the concerns, but for the purposes of this submission we will distinguish between concerns that relate to the driverless vehicles themselves, and concerns about the changes to mobility that the vehicles might introduce ('secondary' concerns).

- Safety
  The dominant concern is about the safety of the vehicle occupants and other road users. Within this broad issue, several aspects can be highlighted:
    - Malfunction of the car computer, leading to crashes or becoming stranded
    - Computer unable to cope with extreme or unusual weather conditions
    - Concern about human drivers causing accidents through misjudging the behaviour of driverless vehicles
    - Concern about the efficacy of drivers taking back control of automated cars

- Security breaches (Hacking)
  Underpinned by numerous movie scripts and a recent demonstration in practice of an automated car being hacked, there is considerable concern about the perceived vulnerability of individual vehicles and the traffic system as a whole. There is potential for many undesirable scenarios if the systems of driverless vehicles are compromised. These concerns are magnified by the high level of connectivity between vehicles, and their integration with myriad other devices that could introduce malware or spyware.

  There are a number of ways that we can respond to this concern with the ultimate aim of driverless vehicles being demonstrated to be safe through successful controlled trials. There are opportunities in the software component development process to implement techniques such as 'security by design' which considers security upfront and integrates security features for products on the drawing board rather than adding them later on. We need to ensure that we are using such high quality systems in Australia or – even better – designing and developing them in Australia for the global industry.

- Data privacy breaches / issues
  People are justifiably concerned about the collection of data and its subsequent use. We need to have a clear understanding of what data that is being collected in order to predetermine how it is used and ensure that people's fears are allayed. A global data governance model that considers all information sources would play an important role here for the 'global good', however there are considerable challenges in setting this up. Any such system would benefit from being implemented by a neutral party.

- Increased costs
  The need for driverless vehicles to be equipped with new technologies means that there are associated costs. As is the case with all technology, the costs reduce as the technology becomes more commonplace and can be amortised over larger numbers of vehicles and so the anticipated rate and extent of adoption have an influence on the size of the price premium.

  However, in the case of driverless vehicles there are some alternative scenarios that could mitigate these cost increases. Many new business models can envisaged, particularly models of shared ownership, that will spread the cost over more people and so reduce the cost per person, per trip, per kilometre and per hour. It could even get to the point where people purchase driverless vehicles as investment opportunities. It is unclear at this stage what the costs associated with new insurance models will be.

Secondary concerns

- Loss of jobs
  There is a lot of media attention focused on the loss of certain kinds of jobs. This includes obvious examples such as vehicle drivers, however it also could include a swathe of white collar office workers involved in the administration and coordination of fleets and freight movement. This issue is part of the broader impact of automation or artificial intelligent on many aspects of society. Stemming the tide of technological development is unlikely to be effective, so our challenge is to identify the commercial opportunities that the new technologies create and attract job creating investment into those areas. Mobility is so central to the operation of our society that we anticipate an explosion of opportunities as people apply the new technologies to different areas. Economic modelling of the likely applications of automated vehicles to the many parts of our mobility task, along with a forecast of the progressive application of driverless technology could help to alleviate some of the anxiety.

- More congestion
  Confusion in the introductory period and induced demand (demand created by the improved technology or conditions that encourages people to move from public transport to driverless vehicles), along with the prospect of driverless vehicles being sent home empty after every trip, may result in increased congestion on the roads. The transitional period of deployment where there is a mix of automation levels on the road, and which could be quite protracted in duration, may result in vehicles

being programmed conservatively in how close they move to other vehicles. This could also mean that benefits from 'platooning' are temporarily less than will be ultimately achievable.

Many of these concerns can be addressed by careful modelling to clarify the risks and causes of negative scenarios, followed by well managed introduction of the new technologies to specifically avoid the anticipated problem.

- Environmental
  Induced demand and empty runs (vehicles performing a task and then returning to base for example) may means that more cars on the road increase emissions.

- Lifestyle
  Cheaper/more mobility options could lead to a more sedentary lifestyle, in turn contributing to obesity.

- Loss of driving skills
  Skills that are not practiced deteriorate and are eventually lost. This could be a concern in scenarios where people spend increasingly smaller periods of time driving.

- Loss of personal choice
  Some people appear concerned that the arrival of driverless vehicles could result in an infringement of their civil liberties by curtailing their enjoyment of being the actual driver of a vehicle.

Other considerations

Our view is that on balance driverless vehicles and associated technologies offer great societal benefits, however in order to extract the maximum benefit we must ensure that the deployment is as effective as possible. With this in mind we would like to comment on a few key areas.

Need for coherent deployment

In order to maximise the benefits available to us from new technologies that automate vehicles we need to ensure that there is a coherent introduction nationwide. We should look to best practice worldwide for how to achieve this and develop mechanisms that support this approach.

Need for familiarity to generate trust

Many studies have shown that trust is key to the successful deployment of driverless vehicles. Careful consideration will need to be given to ensuring that the public has positive experiences with driverless vehicles. Unfortunately the media has a tendency to dwell on the few negative occurrences (such as the Tesla fatality in the US), which leads people to have anxiety about relinquishing control.

There is increasing amounts of data on consumer acceptance of driverless vehicles. We note that studies that anticipate future uptake and acceptance through analysing current acceptance levels have previously been shown to be inaccurate (such as with electric vehicles). As technology, policy changes and familiarity increase, attitudes and perceptions also change.

> ***'Education and exposure may encourage the public to have a more positive attitude towards AVs, but concerns about liability, control and security represent a hurdle'***
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> ***Sun et al, University of WA, University of Sydney (2016)***

Appropriate approvals and regulation
With the National Transport Commission having already identified 716 potential legal barriers for the introduction of automated vehicles in the current federal, state and territory legislation, it is clear that much work needs to be done in this area. Relevant issues include how the vehicles should be regulated, what kinds of vehicles are permitted on the road, the safety standards that should apply, liability regimes and privacy issues.

There is a strong need to consider what validation of safety would look like, and to have visible and trusted testing and ratings for driverless vehicles, such as the ANCAP ratings system that is currently used to rate vehicle safety.

Clarity of liabilities
Current regulation is inadequate in the event of a driverless vehicle crash. In the event that the vehicle causes the crash who should be responsible? The manufacturer of the vehicle, the vehicle owner or the software developer (to name but a few)?

Ethical dilemma
There has been much media attention on the ethical dilemmas associated with driverless vehicles. How does the vehicle decide between alternative courses of action where a crash is unavoidable? Should it protect the occupants, bystanders or the other vehicle / cyclist? This is not a new dilemma, but it is one that is being highlighted frequently in the media and which requires some attention in order for the general public to feel sufficiently safe that they are willing 'grant' the technology a 'social licence' to operate.

Mixed technology levels on the road
Deployment of driverless vehicles will happen gradually and it is likely that for a long period of time (and maybe permanently) there will be a mix of driverless / automated vehicles and non-automated vehicles on the road. This could mean there are issues in the short to medium term with increased congestion as driverless vehicles are programmed to leave additional space (for example between them and the vehicle in front) which is quickly filled by a human driven car, leading to relatively inefficient flows.

A recent study has also shown that human reaction times in taking over control in a semi-autonomous vehicle can be slow - in some cases over 20 seconds (where the 'test driver' is doing an activity other than just watching the road). Having a human driver intervene in the case of a dangerous situation is widely seen as desirable, however if this is perceived to be ineffective due to delays, it could result in resistance to the deployment of automated vehicles.

Both of these scenarios represent situations that may generate negative opinions about driverless / automated vehicles. This transition period will need to be managed carefully to ensure a positive introduction.

Business models
New business models are already redefining the way that we move ourselves and freight. We are now able to share our cars (Car Next Door) and get lifts from other people (Uber, Lyft) and sell vehicle capacity (for freight tasks) on line.

It is generally considered that driverless vehicles will encourage further proliferation of these kind of services by eliminating both the cost and inconvenience of needing a driver (to get the vehicle to a specific destination) and the cost and intrusion of intermediate agents. The flexibility available in such a system can supplement our current and future public transport arrangements leading to fully integrated Mobility as a Service (MaaS) solutions. The potential for improving access to transport is therefore very high and awareness of the options available, which is currently limited to more inner city Sydney and Melbourne, should be promoted alongside the benefits of the driverless technologies.

Australia specific challenges

Australians, despite their relatively limited exposure to driverless vehicles appear to be open to the idea. There are a number of features of the Australian context that need to be taken into consideration:

- Australia is a small market by international comparisons albeit a technologically sophisticated one. It will therefore need to act cohesively to attract investment by overseas technology leaders. Noting that road administration is a State responsibility, we will need to ensure that acceptance of emerging transport technologies is coordinated between States and with the federal government. It will be important to avoid a piecemeal approach.

- The Australian geography is characterised by a number of densely populated urban centres, located on the coastal fringe far apart from one another. It is therefore likely that driverless vehicles will find application in some particular use cases, but may not be suitable for every situation. This means that ‘manual’ and automated driving systems will need to coexist and interface smoothly.

- Australians ‘love affair’ with their own vehicle is a strong cultural thread. A culture of car driving and car ownership is not unique to Australia but it will need to be acknowledged in any plans for the introduction of new technologies.

- Australia is a relatively ‘technology savvy’ community and this creates opportunities not only to obtain early advantage from the use of the new technologies but also, if we act quickly, to participate in the development and global commercialisation of those technologies. Whilst it is true that most of the in-vehicle technologies are being developed overseas, the necessary infrastructure and contextual technologies are still being developed and offer Australia significant technical and commercial opportunities. Australia is already the source for two globally dominant technologies (“DSRC analysis” by Cohda Wireless (SA) and “SCATS” by the NSW Roads and

Maritime Services). We have the possibility to develop these technologies, and more, for the global mobility market, and in doing so create new jobs, economic growth and export opportunities.

Summary and recommendations

The community is somewhat ambivalent about driverless vehicles. They see significant benefits in driverless vehicles, but are concerned about the reliability the systems being developed and the consequences that may accompany system failure. They are unlikely to enthusiastically support and adopt the new technologies unless and until they have more confidence in its reliability and safety.

Therefore we believe the following actions should be taken:

- Increase the community's understanding and experience of the new technologies with a view to building confidence in their reliability, and trust that they are not being exposed to undue risks of damage, injury and death.
- Encourage trialling and demonstration of automated vehicles in a variety of use cases and a wide range of communities.
- Encourage and facilitate opportunities to build community experience. Consider using small-scale deployments to build familiarity and confidence in both rural and city areas.
- Establish and support national coordination mechanisms for the introduction of highly automated vehicles.
- Access and make public, data from vehicle trials in Australia and overseas.
- Establish and apply a methodology for verifying the 'competence' and 'safety' of automated vehicles prior to their release on to the road.
- Establish appropriate cybersecurity arrangements to minimise the risk of hacking, of malevolent interference and to protect individuals' privacy.
- Establish rules for access and use of specific types of data generated from the mobility system.
- Determine appropriate policy settings to avoid undesirable traffic scenarios (such as increased congestion due to automated vehicles making large numbers of 'empty trips')
- Determine appropriate policy settings to ensure that community benefits from automated vehicles are delivered as well as private benefits (such as encouraging all vehicles to be 'connected' to the system and able to co-operate with one another.)
- Encourage the vehicle and insurance industries to develop mechanisms for allocating risk and liability.

Appendices:

i. iMOVE CRC participant inquiry contribution from University of Newcastle
ii. iMOVE CRC participant inquiry contribution from Institute for Choice, University of South Australia
iii. University of Western Australia / University of Sydney Comparative Literature review
iv. Deloitte study – What's ahead for driverless transport
v. Nissan Social Index – Consumer attitudes to autonomous drive

Response from the UoN Group:

Re: Driverless vehicle inquiry

As you may know the House of Representatives Standing Committee on Industry, Innovation, Science and Resources has commenced an inquiry into "the social implications of driverless vehicles".

As described in the terms of reference, they are seeking input from the community on:

Identification of relevant issues, including:

- **Social acceptance**

  Although self-driving cars will still have some accidents which could be prevented by human drivers, we can expect that in total the number of traffic victims will be reduced. This statistics can only be established over time. But if the technology performs as expected then social acceptance will become better.

  The acceptance rate of the self-driving cars is expected to be moderate at the early stage of deployment. There are a number of issues that need to be addressed by the vehicle manufacturer, regulators, service provider, users and others. To develop the confidence of the society it is necessary to develop small scale deployments in the cities and rural areas showing the economic benefits, safer use, and coexistence with other road and pedestrian traffic. Proving failsafe smart technology is extremely important for the wider social acceptance. If the autonomous car industry, regulators and service providers can prove its value then social acceptance will increase rapidly.

- **Passenger and non-passenger safety**

  This is a crucial issue. Driverless cars have to coexist with the legacy cars driven by humans and other road users including cattle's and wild animals in rural areas. How the driverless cars manage themselves and provide security to others is a big question. Situation awareness and response to unexpected or unforeseen events could affect the safety of all road users. For example, when an accident happens between human driven cars, the driver/drivers will stop, park their cars, come out and discuss the issue to take certain actions. What would happen when a driverless car would hit a human driven car or an animal on a road? In this case safety of the driverless car passengers as well as other car driver/passenger becomes an issue. How to tackle adverse weather and traffic conditions to offer safety of driverless cars and other road users. Extensive discussions and research works should be carried out to understand the impact of driverless cars. The outcomes will be different for different countries and/or society.

- **Impacts on employment**

  Self-driving cars will remove professional drivers and their jobs will be lost. However, there will be a new industry that will develop and service autonomous vehicle technologies. This industry could provide many new jobs.
  Obviously this automation area will impact the medium skill jobs of drivers and support staff. However, jobs will move vertically to higher skilled areas. More technical people will be required to support and manage driverless cars. Another area that could be impacted is the car service industry. If the car ownership is reduced due to time shared driverless cars where anyone can get a vehicle by sending a request to the internet or social media. In such case total number of cars in a city or an area could decrease (which is unknown at the moment). In such

a scenario the car service industry as well as the manufacturing industry could be affected. Safer cars will reduce panel beater's jobs! It is also not known whether number of higher skilled jobs in transport industry could compensate for the lost jobs in service and manufacturing industries.

- **Access and equity (such as increasing individual mobility for the elderly and people with disabilities)**

  For elderly and people with disability who do not require general assistance or supervision there will be an increase in independence.

  Mobility of this group will improve, but this group of people will need more human assisted services to use driverless cars. Robots of the future could act as an assistant or guide for this class of passengers.

- **Public transport applications**

  This an area that could be immensely benefited by the driverless cars. Mode of public transport could change, instead of using fixed time scheduled based buses or trains, adaptable or on demand public transport scheduling can be developed. Particularly services in small towns could improve by developing on demand public transport systems. This structure could lead to economic and efficient public transport systems. I think significant research is necessary to develop new mode of public transport system which will be economic, effective and transport passengers with minimum delay.

  In the course of its inquiry, the Committee is also required to have regard to:

- **Non-social aspects relating to driverless vehicles - such as regulatory status, infrastructure, technological readiness, data management and cyber security issues**

  In the last 5-10 years pattern recognition and machine learning based control methods have proven super-human performance in several domains. Over time we can therefore expect that modern computing technologies will help to make self-driving cars safer.

  Regulatory: Appropriate regulatory frame work should be developed to deal with accidents, ride sharing, time shared ownership, ownership requirements (should owner have a driving license or what car knowledge they must have), etc.
  Infrastructure: This is an important area where Australia must research and invest for the seamless integration and adoption of driverless vehicles. Current road traffic systems, road structures, management systems, etc., are not suitable for driverless cars. Also, to improve the safety of driverless cars advanced infrastructure will be necessary. Currently most of the driverless cars are based on self-sensing systems, which will not be adequate when large number of driverless vehicles will coexist with other road traffic users. Similarly current visual signalling systems may not be adequate for future road traffic users. Need to investigate these issues to develop an effective road traffic infrastructure.

- **The experience of other jurisdictions and nations**

  Self-driving car technologies are rapidly developed by almost all nations with significant car industries. Collaborative research centres between universities and car manufacturers such as Audi (Ingoldstadt), Daimler (Stuttgart), and Tesla (Paolo Alto)… have been opened or extended in recent years.

Some examples of systems of self-driving cars and buses worldwide are listed below.

- In USA, currently 6 states are allowing car companies to conduct road tests for driverless cars. E.g., San Francisco has proposed phased plans to deploy autonomous buses and neighbourhood shuttles.
- At Milton Keynes, UK, trials of self-driving pods have already begun. The electric pods will transport people at low speed between train stations and the city centre. Additional UK cities which are experimenting with self-driving car technologies are London, Coventry and Bristol.
- Singapore has launched the Singapore Autonomous Vehicle Initiative, partnered with MIT on future urban mobility and initiated several projects aimed at improving urban transportation systems through self-driving car technology.
- At Wageningen, Netherlands, a project with driverless shuttles (Wepods) is already underway with the aim to revolutionize public transport and provide a new, cost-effective way to bring public transportation to under-served areas.
- At Wuhu, China, self-driving cars and buses will be introduced into the city over the next five years.

The introduction of autonomous vehicle technologies has been progressing in small steps. For example, the SkyLine a fully automatic tram that transports passengers between the two terminals at Frankfurt airport was launched already in 1994 (and similar systems exist at many airports around the world). SkyLine operates in a very constraint environment where automatic driving is possible without much risk. There are autonomous trains and underground vehicles but as their environments are less constrained than the SkyLine it is harder to make operation safe and to be prepared for all eventualities. On freeways autonomous driving could be easier than for cars in cities or off-roads.

Accidents can always happen and in more open environments these are harder to prevent for autonomous or semi-autonomous systems.

In the accident on 7th May 2016 a Tesla car operating in the semi-autonomous mode for the first time killed a person - the driver. The autopilot worked as intended and there is an ongoing discussion who is to blame, the autopilot or the driver who overestimated its abilities.

One lesson learned from this accident is that the responsibility is still with the human who switches a system ON and that the operation of an autonomous or semi-autonomous vehicle. These cars introduces different level of complexities and responsibilities compared to human driven cars. Special driving licenses and extended driver education for operating this new technology are required. Behind every autopilot is a human who can switch it ON or OFF and decide when operation is safe or not.

- **How Australia might best position itself to contribute to global driverless vehicle initiatives**

Driverless car technologies are associated with the big names of the car industry: Daimler, BMW, Tesla, Audi, Toyota, etc.. However, the core technologies are developed by smaller high-quality companies and research groups that are not that well-known and build their success on high-quality products that do not require publicity.

Although Australia has no own autonomous car industry, however it can contribute to the development of core technologies and sell these to the big car companies.

- **The respective roles of the Australian government, the Australian Parliament, other jurisdictions and other stakeholders**

  It will be an important strategy to support Australian industries, start-ups and research groups who can contribute to driverless car technologies. The support should come in-time and include funding, legal support, marketing, etc.

- **How issues identified from this inquiry might inform work on other emerging technologies**

Will help to develop smart city infrastructure work.

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Social acceptance of driverless cars

Driverless cars offer irremediable implications for existing patterns of transportation and land use behavior. These include both short-term decisions, such as places visited and modes of transportation used, and more long-term choices, such as residential and workplace location, car ownership, etc. A greater comprehension of the many factors that will determine these changes is essential to the successful design of infrastructural and regulatory systems that serve the immediate needs of the population while satisfying long-term societal objectives.

Current methods, opportunities and challenges

Any analysis of the potential impacts of driverless cars must necessarily account for ongoing and future competition between ownership-based and sharing-based models of mobility. Many connected and autonomous vehicle (CAV) technologies will likely be offered to potential consumers as both products and services. For example, car companies such as Tesla are planning to integrate automated features within existing car models (O'Neal, 2016). Concurrently, carsharing and ridesharing companies such as Uber are investing in these technologies with the intention of integrating them within existing services. The simultaneous emergence of mobility as a service (MaaS) offers a structural shift in how transportation has been viewed by society.

There are two major challenges towards understanding and predicting current and future acceptance of these new technologies and services: (1) significant proportions of the general populations have likely never heard of driverless car technologies (figures vary, from 34% in the case of Schoettle and Sivak, 2014 to 47% in the case of Bansal et al., 2016) and are unaware of or confused by shared mobility services (up to 81%, as reported by Ballús-Armet et al., 2016); and (2) there is great uncertainty about these technologies and services themselves (what will autonomous cars look like), the supporting infrastructure (will fully autonomous cars run on separated laneways, or will they share road space with existing road users), and the regulatory framework (who will be held liable when an autonomous car is involved in a traffic incident, what will be the insurance costs associated with ownership and use of these cars).

Studies in the past that have sought to understand and predict the adoption and diffusion of similarly new transportation technologies and services, such as electric vehicles, have assumed, implicitly or explicitly, that current levels of acceptance are good indicators of future acceptance. Given the uncertainty and unfamiliarity that surrounds any new technology or service, particularly driverless cars, we argue that the assumption can be severely limiting. As individuals becomes better acquainted with different aspects of the new technology or service, and as the supporting regulatory and infrastructural environment falls into place, public attitudes and perceptions will likely change. Any attempt to extrapolate current preferences to predict future acceptance must therefore control for these coeval changes. Past studies that have ignored these changes have consistently misstated future adoption and diffusion (for an excellent critique of these methods in the case of electric vehicles, the reader is referred to Jensen et al., 2016). Unfortunately, many of these same methods are now being employed to understand and predict the adoption and diffusion of CAV technologies and shared mobility services (see, for example, Bansal et al., 2016; Krueger et al., 2016; Menon et al., 2016; Kyriakidis et al., 2015; Payre et al., 2014; Rodel et al., 2014; Schoettle and Sivak, 2014; Casley et al., 2013; Howard and Dai, 2013), when what is needed is a paradigm shift.

Recommendations to progress action

For much of the last century, transportation planning relied upon gravity-based physical abstractions of population behavior to understand and predict travel demand patterns. In 1972, the National Science Foundation of the United States sponsored a large research project, led by Daniel McFadden at the University of California, Berkeley, for the purpose of developing better tools for transportation planning. The project provided strong evidence that utility-based economic abstractions of individual behavior could outperform conventional methods, and that these new procedures were more sensitive to the operational policy decisions facing transportation planners (McFadden, 2001). The resulting framework has since been widely adopted for transportation planning around the world. And for his contributions to the research project, McFadden was awarded the 2000 Nobel Memorial Prize in Economic Sciences.

The introduction of CAV technologies and shared mobility services offers an opportunity for a paradigmatic shift of similar proportions. Since the seminal work of McFadden and others during the 70s and 80s, a number of notable advances have been made with regards to methods for both data collection and analysis. We have access to more data of greater quality and higher resolution than was ever available before, through various disparate sources that include traditional surveys, smartphone censors, online social media, virtual reality simulators, and real-world field tests. We are able to estimate behaviorally richer and mathematically more complex models of travel demand than were ever possible before, due largely to advances in computational power, optimization routines, simulation methods, etc. The time is ripe for a concerted effort, similar in spirit to the research project hosted at Berkeley in 1972, to integrate this progress towards the development of a new and improved suite of tools for transportation planning. Australia is home to some of the leading researchers in the field, many of whom are part of the iMove CRC. With support from the government, such an endeavor could position Australia at the forefront of the transportation planning profession.

Note: I'm unsure about the kind of recommendations the inquiry is looking for, so happy to defer to your judgment, but I think a definite case can be made for encouraging greater research in the area. If you think this will be of interest, and need more detail, please don't hesitate to ask.

References

Ballús-Armet, I., Shaheen, S., Clonts, K., & Weinzimmer, D. (2014). **Peer-to-Peer Carsharing: Exploring Public Perception and Market Characteristics in the San Francisco Bay Area, California.** *Transportation Research Record: Journal of the Transportation Research Board*, (2416), 27-36.

Bansal, P., Kockelman, K. M., & Singh, A. (2016). **Assessing public opinions of and interest in new vehicle technologies: An Austin perspective.** *Transportation Research Part C: Emerging Technologies*, *67*, 1-14.

Casley, S., Jardim, A., & Quartulli, A. (2013). **A Study of Public Acceptance of Autonomous Cars.** *Worcester Polytechnic Institute*.

Howard, D., & Dai, D. (2014). **Public perceptions of self-driving cars: The case of Berkeley, California.** In *Transportation Research Board 93rd Annual Meeting* (No. 14-4502).

Jensen, A. F., Cherchi, E., Mabit, S. L., & Ortúzar, J. D. D. (2016). **Predicting the potential market for electric vehicles.** *Transportation Science*.

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). **Preferences for shared autonomous vehicles.** *Transportation research part C: emerging technologies*, *69*, 343-355.

Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). **Public opinion on automated driving: results of an international questionnaire among 5000 respondents.** *Transportation research part F: traffic psychology and behaviour*, *32*, 127-140.

Lesnick, P. C. (2000). **Technology transfer in the Dominican Republic: A case study of the diffusion of photovoltaics.** *PhD dissertation*.

McFadden, D. (2001). **Economic choices.** *The American Economic Review*, *91*(3), 351-378.

Menon, N., Pinjari, A. R., Zhang, Y., & Zou, L. (2016). **Consumer Perception and Intended Adoption of Autonomous-Vehicle Technology: Findings from a University Population Survey.** In *Transportation Research Board 95th Annual Meeting* (No. 16-5998).

O'Neal, L. (2016). **Are Driverless Cars Safe? Elon Musk Says Tesla Will Roll Out Self-Driving Feature In 'About Three Weeks' Despite Recent Crashes.** *International Business Times* Web, 28 Nov 2016.

Payre, W., Cestac, J., & Delhomme, P. (2014). **Intention to use a fully automated car: Attitudes and a priori acceptability.** *Transportation research part F: traffic psychology and behaviour*, *27*, 252-263.

Rödel, C., Stadler, S., Meschtscherjakov, A., & Tscheligi, M. (2014, September). **Towards autonomous cars: The effect of autonomy levels on acceptance and user experience.** In *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 1-8). ACM.

Schoettle, B., & Sivak, M. (2014). **A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia** (No. UMTRI-2014-21).

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Road to autonomous vehicles in Australia: A comparative literature review

Yuchao Sun[1*], Doina Olaru[1], Brett Smith[1], Stephen Greaves[2], Andrew Collins[2]

[1]The University of Western Australia (PATREC)

[2]University of Sydney, ITLS

Email for correspondence: chao.sun@uwa.edu.au

Abstract

Autonomous vehicle technology and its potential effects on traffic and daily activities is a popular topic in the media and in the research community. It is anticipated that AVs will reduce accidents, improve congestion, increase the utility of time spent travelling and reduce social exclusion. However, knowledge about the way in which AVs will function in a transport system is still modest and a recent international study showed a lower familiarity with AVs in Australia compared to USA and UK. Attitudes towards fully automated driving (or higher levels of autonomy) range from excitement to suspicion. The breadth of feelings may be due to the low level of awareness or reflect polarising attitudinal positions. Whilst experts appear to be more confident about the adoption of AV technology in the near future, public acceptance is key to AVs' market success. Hence, research that examines local contexts and opinions is needed.

This paper reviews existing scholarly work and identifies gaps and directions for future developments, with a focus on the Australian context. The review will address the following broad categories: investigation of AV features and mobility models, implications for road traffic and connectivity to infrastructure (especially in low to medium density urban areas), public attitudes and concerns, potential business models, and policy implications. The aims of the paper are to identify critical issues for the development of a focus group inquiry to understand attitudes of potential users of AVs and to highlight AV development issues for policy makers in Australia.

1. Introduction

Autonomous vehicles (AVs) have been the subject of wide-spread attention over the last few years featuring in government reports, research studies, media articles, blogs, novels and even movies. AVs have captured the imagination and interest of stakeholders through their potential implications for transforming personal mobility and society as a whole (Schoettle & Sivak, 2014a,b; Howard & Dai, 2013: Kyriakidis et al., 2015; Madigan et al., 2016). In a recently released Smart Cities Plan, the Australian Government (2016) advocates a 'technology first' approach to solve our planning challenges. It lists AVs as a transformational technology that will have fundamental impacts on our cities. Although few will argue against this, there are still many unknowns associated with AVs, from both social and technical aspects. For example, attitudes towards fully automated driving (or higher levels of autonomy) range from excitement to suspicion (Bazilinksy et al., 2015; Kyriakidis et al., 2015). Some anticipate that AVs will reduce accidents, improve congestion, increase the utility of time spent travelling and reduce social exclusion, while others remain unconvinced. This is partly due to our limited understanding about the way in which AVs will function in an already complex transport system.

The uncertainty and divided opinions around AVs together with general inertia in transportation systems, suggests that significant time will be required before we see AVs running down city streets on a large-scale. In a recent study of 109 countries and 5,000 participants, Kyriakidis et al. (2015) found that almost one-third of participants do not believe that fully automated AVs will reach 50% market share before 2050. Compounding this, Australia is a relative laggard in the AV space, with a handful of trials (discussed later in the paper) but as yet no firm direction from the federal level. Interestingly, a recent study suggests Australian respondents had the highest general positive opinion compared to those from the U.S. and UK (Schoettle & Sivak, 2014a).

Within this context, this paper reviews recent experiences of AVs and speculates on what the future might hold for Australia. While there are a myriad of levels of automation, for this review we focus primarily on full-time automatic driving with no requirement for human intervention. Section 2 provides some historical milestones in the evolution of AVs, Section 3 presents the impact of AV on traffic, followed by public acceptance and likely demand changes (Section 4). Business models are included in Section 5 with policy impacts covered in Section 6. Finally, we present an overview of current trials in Australia before drawing some concluding thoughts.

2. Evolution of AVs

While the terms *autonomous* and *automated* are closely related, they have been loosely used. The US National Highway Traffic Safety Administration (NHTSA) defines automated vehicles as those capable of actuating at least some mission-critical controls with no human intervention (NHTSA, 2013), most of which are related to longitudinal and lateral movement of the vehicle (Le Vine et al., 2015). NHTSA classifies five levels of automation (level 0-4), ranging from no automation to full automation. By comparison, the Australian National Transport Commission (NTC, 2016a) adopts Society of Automotive Engineers (SAE) International Standard J3016 (2014) that defines six level of automated driving (level 0 – 5). Most people's understanding of the term autonomous vehicle would probably refer to the highest level in both definitions, which means vehicles can make end-to-end trips independently. Nevertheless, there are also partial AVs, which can perform autonomous driving under certain circumstances.

Shladover (2009) argues that autonomy and automation are two different and orthogonal concepts. He defines autonomous as the opposite to cooperative so a vehicle could be fully automated but not cooperative, i.e. it purely works on local information gathered by its sensors, with no vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication. In fact, Shladover and others suggest that autonomous vehicles are likely to produce limited or no benefits to traffic performance without being connected, an issue, which impacts dialogue attesting to their individual and societal benefits. On the other hand, autonomous driving provides the technical basis for unleashing their full potential of vehicular communication in the form of autonomous interaction between vehicles (Dresner & Stone, 2008).

3. Impact on Traffic System Performance

One of the most highly anticipated benefits of AVs is improved traffic flow. The potential improvements are in forms of increased intersection capacity, increased traffic throughput and vehicle platooning, which will be considered in the following subsections.

3.1 Stabilising Traffic Flow

Imperfect human driving behaviour (Orosz & Stépán, 2006; Zhang & Orosz, 2013) often causes instable traffic flow so there is much hope that robotic driving systems are able to reduce congestion on freeways by stabilising traffic flows.

Currently, there is insufficient evidence on how driverless vehicles will behave, plus there will be natural variations between different brands. Nonetheless, their likely effect on freeway traffic can be estimated by looking into the relatively large body of research on Adaptive Cruise Control (ACC) systems. These systems perform lower level of automation by NHTSA and SAE's definition. They control the vehicle's longitudinal motion based on local information gathered from the vehicle's forward-looking sensor, which monitors the movement of the immediately proceeding vehicle and try achieve the desired speed when it is safe to do so (Arnaout & Arnaout, 2014). One would expect AVs will have similar driving characteristics to vehicles with ACC under certain conditions, especially in the freeway main lines.

Unfortunately, there have been contradictory conclusions on whether ACCs can improve traffic flow when mixing traffic with human drivers (Arnaout & Arnaout, 2014). Even if they can, there has to be a minimal market penetration in order to achieve a notable improvement - the same argument holds true for realising safety benefits, which will be discussed later. The estimates vary largely, typically from 10% (Kesting et al., 2008) to 60% (VanderWerf et al., 2003).

The limitation of ACCs is their total reliance on their local sensory inputs information. It is difficult to detect the preceding vehicle's acceleration with very high accuracy and low latency so typically a minimal headway of 1 second or higher is assumed (Shladover, 2009; van Nunen et al., 2012), which is an improvement on human's gap acceptance of about 1.5 seconds (Shladover, 2009), but probably much lower than most people imagined. Horn (2013) has proposed a bilateral ACC, which not only looks forward but also backwards, and claim it can stabilise traffic flow at high density. However, it requires most cars to be equipped with this system.

Consequently, cooperative adaptive cruise control (CACC) has been proposed (e.g., Davis, 2007; Arnaout & Arnaout, 2014) to overcome the limitations of ACC by vehicular communication, maintaining so-called string stable platoons (Ge & Orosz, 2014; Davis, 2004), which is difficult for human drivers due to their slow reactions (Zhang & Orosz, 2013). In addition to higher level of service, stable traffic flows also have the benefit of reduced energy consumption through less stop-and-start.

3.2 Platooning

Another most publicised advantage of automated driving is the ability to form platoons, especially on the freeways. The main advantages of platooning include higher density and the reduction of energy consumption because of reduced air drag (Shladover, 2009). Empirical data from California show that human drivers need about a 1.63 second gap between vehicles, so at the speed of 100km/h this leaves around 11% of longitudinal length utilisation (Shladover, 2009). Platooning is hoped to increase throughput through larger vehicle density. However, research again suggests that isolated AVs will not be able to perform this task effectively without V2V communication (Liang & Peng, 2000; van Nunen et al., 2012). There are also concerns on how platoons interact with non-equipped vehicles and the potential negative impacts on ordinary drivers in a mixed traffic (e.g. Gouy et al., 2014).

3.3 Accidents

Clearly, reducing accidents will increase travel time reliability and reduce congestion (NHTSA, 2013; Fagnant & Kockelman, 2015). Given that human errors are responsible for over 90% of crashes, it is reasonable to assume AVs will be generally safer. As pointed out by Fagnant & Kockelman (2015), while there is the potential for machine failures and hacking, AVs do not drink and drive, do not drive tired, get distracted, or use drugs, do not speed or break laws. These were the main factors listed by the U.S. National Highway Traffic Safety Administration in 2012, where 93% of the total crashes had a human cause as a primary factor (p. 169). However, benefits depend on the proportion of AVs in the traffic mix (ibid.) and the communication between vehicles and infrastructure (Petit & Shladover, 2015), because while an AV can be programmed to be logical, conventional traffic cannot. On-road trials of AVs in mixed traffic in the U.S., attest to this issue with higher crash rates (on a per kilometre basis) reported for AVs, largely from being hit by conventional vehicles.

3.4 Intersection Capacity and Comfort

Intersections present more challenges to AVs than freeways because of more conflicting movements (Li et al., 2013). Researchers have envisaged new ways of intersections controls incorporating AV technology, which would improve intersection capacity (e.g. Li et al., 2013; Tachet et al., 2016; Lu & Kim, 2016; Dresner & Stone, 2008; Guler et al., 2014). Some require radical departure from the conventional signal controls such as the slot-based system (Tachet et al., 2016), for which market acceptance would be a challenge; others are designed to work with a mixed flow of human driven vehicles and AVs (e.g. Guler et al., 2014). Most of these systems require V2I/V2V communication. Florin & Olariu (2015) provide a recent review on how vehicular communications can be used for signal optimisation. Much of the current research focuses on analysing single intersections, which is the necessary first step, but it will be interesting to see how much improvement they can achieve in a network where interaction and coordination of the intersections would have an impact.

Besides potential capacity improvement, the autonomous intersection management systems might also improve passenger comfort, especially given that they have the possibility of removing the need for roundabouts that are prevalent in Australian suburbs. Small suburban roundabouts are probably one of the major contributors to bus passenger discomfort because they are difficult for large vehicles to negotiate. They may no longer be needed for suburban roads with low volumes if all vehicles are autonomous. AVs could be coordinated safely using automated negotiation and allocation mechanisms.

Infrastructure investment aside, V2V/V2I communication implementation would require a significant transition time. In the interim, how disconnected AVs (that purely reply on local sensors) would interact with the conventional signalised intersections' capacity is less clear. Le Vine et al. (2015) cast doubts on the potential impact of AVs to the existing signalised intersections, if not integrated with V2V/V2I communication. This could be also extrapolated at the link level and the road network. Le Vine et al. (2015) also concluded that if AVs are designed to prioritise passenger comfort, they might actually decrease intersection capacity and cause longer delays to vehicles (comparing to the all human-driving base case).

The issue of passenger comfort of AVs has been mentioned by a number of authors. There are some possible technical solutions to the problem, such as tilting the vehicle to counter the longitudinal and lateral accelerations (Le Vine et al., 2015), but how much cost they would add is unknown, especially to large vehicles. In addition, the potential for AVs to enable different more productive or enjoyable time use, raises the question of the trade-off between 'smoothness' of the ride and the quick reaction time, which offers the capacity growth.

4. Impact on Travel Behaviour and Demand

Any study looking at the future of new technologies should evaluate the determinants of the adoption process. Given that consumer preferences, socio-economic factors, as well as social interactions influence the pathway and speed of adoption, we start by presenting the advantages and limitations of AVs, as seen by the public.

4.1 Induced Demand

Given their potential to dramatically change mobility and provide personal independence and better travel conditions, AVs may generate substantial new demand. As, shown below, AVs may facilitate travel for segments of the population currently excluded, and offer comfortable travel conditions, conducive to a more productive and/or enjoyable time use. This could change the perception of value of time (VOT), i.e. reduce the 'time cost' of travel, which in turn may induce higher demand, by taking more trips and at longer distances than before. This is what the literature refers to as the primary demand. There is also a less desirable effect that may be associated with the new demand: empty runs or long parking times for vehicles that are doing only point-to-point services, further urban sprawl by relocating to more attractive or less expensive areas (because travel cost decreases and utility increases).

These aspects are presented in more detail next.

4.1.1. People with mobility restrictions

One of the main appeals of autonomous vehicles is their ability to address equity and offer access for a number of currently disadvantaged groups, such as elderly (with notable decline in vehicle license holding and age-related impaired driving aptitudes) and individuals with disabilities (which preclude them from driving) (Howard & Dai, 2015; Fagnant & Kockelman, 2015; Anderson et al., 2016). This was consistently highlighted as a 'plus' for AVs, because enhanced mobility is associated with positive quality of life and health outcomes.

In addition to individuals unable to drive, AVs create mobility solutions for those unwilling to drive or prohibited from driving for various reasons. Thus, regardless of the circumstances that lead to losing the privilege to drive, AVs provides a corrective solution for the lack of mobility, which may hinder social interaction and participation in community life. Lack of independent mobility could result in critical reductions in wellbeing and negative symptoms, and although public transport and other on-demand solutions may alleviate the situation, they are not seen as being as flexible as AVs.

Yet, in order to be accessible, a shared use model for AVs should be in place. Considering their expected high purchasing cost, shared AVs are the *"most affordable way for people to access self-driving technologies and its associated benefits"* (Howard & Dai, 2015: 5).

4.1.2. Better/more productive time use

A fully automated vehicle means that the driver is 'released from her/his duty' behind the wheel and this opens up the opportunity for other activities to be conducted during the trip. Combined with the likelihood of a transformed layout of the vehicle, the AVs offer the benefit of converting travel time to reach various locations into productive and/or more enjoyable activities: working, resting, eating meals, watching movies, reading books or magazines, making phone calls, socialising (Schoettle & Sivak, 2014a; Fagnant & Kockelman, 2015).

In the context of an increasing 24/7 economy and with the diffusion of work hours outside standard 9am to 5pm, the potential to conduct other less stressful or demanding activities during driving could potentially improve the social interaction and work-life balance for many individuals (Wight et al., 2009).

The three country comparison by Schoettle & Sivak (2014a) showed that after “watching the road”, the next top choices of activity while riding the AV were: “reading” (#1 in US and UK and #3 in Australia); “text or talk with friends/family” (#1 in Australia, #2 in the US and #3 in the UK); and “sleep” (#2 in the UK and Australia and #3 in the US) (p.18).

This has a direct effect on the VOT, which may decrease substantially, due to productivity gains and or higher utility of travel, with policy implications for evaluating alternative transport projects (where VOT savings is a core element in cost-benefit evaluations).

4.1.3. Eliminating negotiation between family members

Autonomous vehicles also enable those too young to drive by themselves to be taken to their activities, with or without the company of an adult. This may resolve the challenges of trip chaining and sequencing of activities for parents. They are often forced to organise their own work at other hours than the children’s school program and to negotiate their schedules. As indicated, this is expected to have positive impacts for individual and family wellbeing (Wight et al., 2009).

AVs may solve some of the “disruptions” of family routines (Wight et al., 2009) by either allowing all family members to be together during the AV ride (having family time, relaxing together, or conducting other activities, separately), or freeing adults to undertake work and non-work activities at other locations than their children.

The latter case assumes that parents and carers would be comfortable to let their children be ‘free range’ in the company of a robotic vehicle, with various degrees of monitoring for the trip. Furthermore, by eliminating the joint travel, these new movements generate extra road capacity demands, especially if they are not spread evenly during the day.

4.1.4. Secondary demand (extra movements, empty runs)

AV operation, not requiring human presence, facilitates delivering freight and not licenced individuals reaching their destinations. However, if AVs do not serve multiple demands (as in a shared program), the empty runs after deliveries and drop-offs may increase the number of vehicles on the road and the mileage (e.g., if the AVs are self-parking in less expensive areas).

This suggests that a shared mobility model (on-demand services) holds great promise for traffic conditions, despite the concerns around loss of personal space and loss of control (a demand for travel is not considered in isolation, so dependency on others is not removed).

The extra movements and distances depend heavily on the level of AV penetration. Fagnant & Kockelman (2015) estimate an excess of 20% at 10% AV market share, but only 10% at 90% market share (p.172).

4.2 Public Negative Attitudes

AV uptake is a complex issue and a highly convenient mobility option comes with negative impacts as well, some of which are hard to anticipate at the moment: greater obesity, loss of competencies and skills (Bazilinskyy et al., 2015), over reliance on machines (Trimble et al., 2008; Howard & Dai, 2015). The range of individual concerns already expressed include: lack of trust in the capabilities of AV and their networking (Fraedrich & Lenz, 2014); specific risks for crashes (Daziano et al., 2016) that may be generated by non-AV traffic participants (Bazilinskyy et al., 2015), hacking of the systems (Fagnant & Kockelman, 2015), data transfer to third parties, deprivation from the joy of driving (Fagnant & Kockelman, 2015; Kyriakidis et al., 2015).

Carlson et al. (2014) report that trust increases with the past performance of the system, with research on reliability or validation of the system, and through the reputation of the designer and manufacturer of the system; still, numerous trust issues are still unresolved and under review (Howard & Dai, 2015; Kyriakidis et al., 2015). The classical dilemma of ‘who is the AV saving?’ in a crash produced by a fallen object or an inattentive cyclist on the road, suggests that the public is equally unlikely to leave this decision in the hands of a computer scientist incorporating rules of operation for AV or of a machine, learning from itself how to drive safely.

Trimble et al. (2014) argued that two of the three types of trust (overtrust and distrust as opposed to calibrated trust) may affect the uptake of AVs. Whereas calibrated trust (match of individual beliefs and system capabilities) supports appropriate application, overtrust can lead to misuse and distrust to disuse, which are equally damaging. Extended periods without performing driving may also lead to losing this skill, as memory fades and driving reactions may be less efficient. This is seen as problematic, especially if there is a need to override an AV.

Related to this, AVs may erode the internal locus of control (Howard & Dai, 2015), or the perceived possibility to control events. Schottle & Sivak (2015a) showed that 96% of their sample expressed the desire that steering wheels, brake pedals, and some controls remain available in AV cars.

Many members of the community have raised issues of privacy, likely to increase once data sharing and V2V/V2I communication become mainstream operation. Using current examples of intelligence collected on purchasing preferences and searches, or from monitoring of personal activity patterns, apprehensions about “who would own and control the data” and “with who is shared and for what purpose”, are well founded.

Finally, electronic security concerns are also at the top of the list of issues to be resolved (Schottle & Sivak, 2014a,b; Kyriakidis et al., 2015). *“Computer hackers, disgruntled employees, terrorist organizations, and/or hostile nations may target AVs and intelligent transportation systems more generally, causing collisions and traffic disruptions.”* (Fagnant & Kockelman, 2015: 177). Their study distinguished between the acts of espionage (information gathering) vs sabotage (compromising the system’s normal operation). Whereas for the individual the former gets more prominence (responsibility for good operation of the system is seen as an organisational aspect), tampering with the system could have long lasting repercussions.

4.3 Summary of Perceived Benefits and Barriers

Several large sample public opinion studies have highlighted positive attitudes (Payre et al., 2014), as well as *“non-negligible level of reluctance”* (Kyriakidis et al., 2015: 128). This mixture/ambivalence towards autonomous vehicles is expected considering the uncertainties surrounding the technology (Daziano et al., 2016). However, level of awareness and cultural differences, have led to a wide range of attitudes around the globe. For example, people in Germany and China were more aware of the AVs compare to those in Japan (Sommer, 2013) and more US respondents have heard about AVs compared to the UK and Australian counterparts (Schoettle & Sivak, 2014a). What is more, using a nation-wide online panel, Daziano et al. (2016) drew attention to the substantial heterogeneity in preferences for automation of the US respondents, with a substantial share of the sample willing to pay more than $10,000 for automation, when an equally large number is unwilling to pay any amount. This suggests that flexible policies may be required for a successful adoption of the technology.

This may be associated with the more positive attitudes towards AV: more positive responses and fewer negative responses were received from the Australian sample, than UK and US (Schoettle & Sivak, 2014a); similarly, respondents in China and India are substantially more interested in acquiring AVs than the Japanese respondents (Schottle & Sivak, 2014b).

Comparable differences are shown when expert opinion is elicited. A survey of London transport professionals showed hesitation that the timing for level 3 and 4 AVs to become commonplace would be earlier than 2040 (Begg, 2014), whereas participants in the Automated Vehicles Symposium 2014 saw 2030 as feasible for full automation freeway driving (Underwood, 2014).

Coming back to studies focusing on Australian respondents, a number of benefits were cited within Schoettle & Sivak (2014a): safety, as AVs would lead to reduced crashes (72.3%); reduced severity of crashes (73.5%); improved emergency response to crashes (68.7%); less traffic congestion (47.5%); shorter travel times (44.8%); lower vehicle emissions (62.3%); better fuel economy (70.1%); and lower insurance rates (54.6). Despite these positive results, only 12.7% of the Australian sample indicated that they would not be concerned at all about driving or riding in a level 3 AV or 11.5% in a fully automated vehicle (Schoettle & Sivak, 2014a, Table 3, p.9).

To conclude, education and exposure may encourage the public to have a more positive attitude towards AVs, but concerns about liability, control, security represent a hurdle and will take some time before AVs will be accepted.

5. Business Models

The current high price of AVs raises questions the feasibility of owning versus sharing such a vehicle. Presently worldwide, 5.8 million people make use of a shared fleet of 86,000 vehicles. This is expected to grow dramatically by 2021 to 35 million participants booking 550,000 cars in an industry worth AUD$7.5 million per annum (Bert et al., 2016). The shift to diverse mobility solutions may mean that up to 1 out of 10 new cars sold in 2030 are likely to be used as a shared vehicle (McKinsey & Company, 2016). It would seem that the expansion of car sharing models will progress without the advent of fully automated vehicles. However, the prospect of a completely self-navigating vehicle, sometime in the future, will continue to encourage investment in mobility sharing technologies. This is because a fully autonomous vehicle is potentially cheaper than models that require a human driver.

In addition, driverless vehicles offer a more streamlined business model in that transferring vehicle insurance could be avoided. Insurance is a particular concern for public and private companies increasing their ridesharing activities, such as Uber. A new hybrid model may replace the driver-partner sharing model to an entrepreneur sharing model, which eliminates the driver. This would significantly change the car sharing landscape. The Uber's CEO, Travis Kalanick, freely admits that the driver is the most expensive part of its operations, as well as citing that legal issue of whether drivers are employees or contractors as being a current challenge to their business model (della Cava, 2016). Both these issues may be alleviated by removing the driver from the service.

Operationally, the AV lends itself to ride sharing because it solves the relocation problem faced by one-way sharing models (Firnkorn & Muller, 2015). Relocating AVs will involve some degree of empty running. However, the amount of empty kilometres could potentially be halved under a system of dynamic ride sharing, whereby more than one passenger destination can be serviced on the same trip (Fagnant & Kockelman, 2015). To achieve this, passengers would need to be somewhat more flexible in their schedule and accept longer trip times.

In a recent stated choice exercise, younger travellers who identified themselves as being multimodal stated a higher intention to participate in dynamic ride sharing (Krueger et al., 2016). Furthermore, these respondents were more likely to be currently using ride sharing and car sharing applications. Not limited by the discussion being on autonomous vehicles, there is strengthening evidence that the next generation of independent travellers may not purchase their own car and may be more willing to pay for mobility services. Over recent years, younger people in Australia were less likely to obtain a driver's licence (Delbosc &

Currie, 2013) and seemed less influenced by the status and hedonic qualities of vehicle ownership than their parents (Delbosc & Currie, 2014).

As indicated in Section 4.1.1., fully autonomous vehicles can improve the outcomes for the segments of the community that are unable to drive. However, Anderson et al. (2016) pointed out that public authorities already provide paratransit services, but at a considerably higher cost than fixed route public transport services. From the point of view of sharing or flexible mobility models, the delivery of an affordable service seems to come down the cost savings made by removing a professional driver from the equation.

The role of autonomous vehicles may extend into the regular public transport space. There is much less research on autonomous public transport networks than on driverless cars, with the exception being output from the City2Mobile project (e.g, Alessandrini et al., 2014). The concentration of research on the private vehicle may be counter intuitive because finding dedicated lanes – avoiding interactions with human drivers – is far easier for existing public modes. Alessandrini et al. (2015) indicated that different urban types would benefit from different automated public transport models. More dense corridors would benefit from high–tech buses, capable of platooning, but lower density suburbs would lend themselves to shared vehicles and on demand public transport acting as feeder services.

It is evident that the shared mobility models will continue to grow before AVs become mainstream. However, the prospect of driverless vehicles will reassure investment in this sector because of the unmistakable cost saving. At present car sharing has its strongest hold in inner city Sydney and Melbourne (Dowling & Kent, 2015). However, this is predominately due to the car-club models being affordable to households who need to make fewer trips by cars (Castle, 2015). New business models of peer-to-peer sharing, such as Car Next Door, also demand monthly fees and high per use charges making them suited to the inner city, car free culture. The advent of driverless vehicles will blur the line between taxis and car sharing companies and may indeed undermine the club membership model. Furthermore, public authorities need to decide what role they will play in this market and whether the first and last mile is left to the private market or whether driverless on demand public transport will provide feeder services in low density Australian cities. Yet, driverless rail and busways offer lower technology options than fully autonomous vehicles that need to share the lane with human drivers. Mass public transport links appear to be an obvious entry point for driverless technology on our networks.

The previous discussion has indicated that AVs could have direct impacts on personal mobility, travel demand, system efficiency, reduced externalities, parking, public transport and other types of shared transport services. In addition, effects may be felt in other sectors of society due to the lowering of marginal costs (largely because there will be less need to own a vehicle) and opportunity costs that is likely to accompany large-scale introduction of AVs. For instance, people may choose to live further from work and other activities where housing is more affordable and make longer trips. A further impact could be the loss of many jobs in the professional driving sector, as drivers are replaced with robots. All these issues create challenges for policy-makers, without whose support, AVs will likely remain confined to fiction.

6. Policy Considerations

6.1 Regulatory Issues

The introduction of AVs, will require significant changes in regulatory frameworks and liability regimes. The Australian National Transport Commission recently identified 716 potential legal barriers in the current federal, state and territory legislation (NTC, 2016a; NTC, 2016b; NTC, 2016c). Among the most pertinent issues for consideration are if/how AVs should be regulated, what types of vehicles should be allowed on the road, safety standards, liability regimes, and privacy issues. An additional consideration in Australia is what elements of AV regulation should come under federal and/or state legislation. Clearly, a coordinated approach is needed to ensure consistency across the country and to international standards (NTC, 2016c). This is particularly so when considering V2I/V2V communication plays an important role in unleashing the full potential of AVs. Commentators have recently cautioned Australia not repeat the same mistake on rail gauges (Retter, 2016).

As a relative laggard in the AV space, Australia does have the (comparative) advantage of learning from regulatory efforts overseas. In the U.S., several states have passed legislation permitting on-road trials of AVs under specific circumstances (although equally interesting is that several have failed to do so), and federal policy guidelines have recently been published to provide assistance for testing, licencing and registration of AVs (NHTSA, 2013). Within Australia, most of the federal push for legislation is coming from the NTC, although ANCAP as the main regulator of new vehicle standards is also clearly a key player. A key issue, as with the U.S., is that while testing of vehicles is a federal level prerogative, testing of drivers is done at the state level. As Anderson et al. (2016) point out, this could cause complications for AVS, because essentially the driver is now the vehicle.

6.2 Liability and Insurance

If AVs result in the levels of safety benefits alluded to earlier in this review, then insurance costs should go down. However, as yet, this is a big unknown, particularly if operating in mixed traffic as seems a probable scenario initially at least. Irrespective, it is unlikely current insurance models will work with AVs as it seems unreasonable to have the individual underwrite a vehicle that is operating autonomously. Suggestions are that the manufacturer of the vehicle and/or makers of the software components themselves could bear a larger brunt here, which could in turn stifle the introduction of new technology (Anderson et al. 2016). Further complexity is introduced for various reasons. First, the decision on what to do in the event of a possible crash now shifts from the driver to the machine and/or programmer. In turn, this could result in challenging decision around, given a choice, whether the vehicle occupants are the priority or other road users. Second, it is probable that there will still be some level of human override as we transition to total automation, which raises questions around the shared liability. Third, even under a fully automated regime, it is probable an AV will still be responding to user directions to some extent in terms of directives to pick them up/drop them off under specific conditions. For instance, if it is raining heavily, will the pricing regimes change and/or will there be certain conditions when the vehicle is programmed not to come and pick up a passenger?

6.3 Broader Policy Issues

As alluded to earlier in this review, AVs could have many tangential effects on mobility, location choice and others, which we cannot yet anticipate. One area that has received recent press, is that of the potential impacts of AVs on parking requirements (Anderson et al., 2016). Provision of sufficient parking capacity in dense, urban areas is a perennial issue. It is a constant source of angst for both private travellers and businesses with parking-related searching contributing significantly to wasted VKT and associated negative externalities. Parking provision is also expensive both for the authority and consumer, but it provides a significant source of government revenue, both indirectly through taxation and directly through payments and fines. In theory, AVs should reduce parking demand because once a passenger has been dropped off, the vehicle can then go on to pick up another passenger. With estimates as high as 30% of vehicles on city roads searching for a parking space, the potential impacts of the removal of this traffic are clearly significant (Shoup, 2005). Looking further ahead, if AVs take off on a large-scale, this could reduce the demand for dedicated parking space, which could be converted to other land-uses of a more amenable nature such as parks and pedestrianised areas. However, this change is unlikely to happen without significant pain as many car-parks (e.g., multi-storey) are difficult to repurpose; moreover, car parks represent a significant source of revenue, implying that councils may have to look to make up the revenue shortfall through other charging mechanisms. In addition to revenue decline, AVs would also make parking an ineffective travel demand management tool. Owners might order AVs to seek cheaper parking or even roam or return to the base, especially if the roads are not priced (Sun et al., 2016).

7. Snapshot of AV Research and Trials in Australia

In Australia, other than the National Transport Commission leading the legislative review, the Australian Driverless Vehicle Initiative (ADVI) plays a significant role in coordinating AV activities at the national level. This started from the Driverless Vehicle Roundtable held in Sydney in 2014 at the 26th ARRB Conference, the result of which was summarised in a workshop report (Hillier et al., 2014). However, most of the actual research and trials are in a state of competitive federalism featuring a healthy contest between states and territories governments and institutions located in their boundaries. In this section we provide a snapshot on the AV research and trials around the country. Given the scattered nature of the activities, this is by no means a complete list and we acknowledge this may not cover all projects.

The Queensland government is cooperating with Bosch and QUT's Centre for Accident Research and Road Safety (CARRS) to test retrofitted AVs in its road network (Galvin, 2016). The government also commissioned an independent review, 'Opportunities for Personalised Transport (OPT)' in October 2015, looking into a range of future trends in personal mobility including shared AVs (Washington et al., 2016). Tranter (2016) has concluded that much of Queensland's road and criminal laws can be adjusted to accommodate AVs and he also identified areas needing reform.

In NSW, the UNSW Research Centre for Integrated Transport Innovation (rCITI) partnered up with car sharing company GoGet to develop AV technology (UNSW, 2014). Krueger et al. (2016) have used stated preference surveys to investigate the likely adopters of shared autonomous vehicles and their willingness to pay in terms of critical service attributes.

The ACT government and its opposition have both shown strong support for attracting AV trials (ABC, 2016). In Victoria, the government is funding $4.5 million to the development of Intelligent transport Systems which presumably include AV technology (Victoria State Government, 2016). The neighbouring state, South Australia, has hosted the International Driverless Cars Conference and its first AV trial with Volvo in 2015. In 2016, it became the first state to pass legislation that allows AV trials subject to approval by the transport minister (Tucker, 2016).

In Western Australia, RAC (2016), with the support of the state government, has purchased a French-made driverless electric bus, which can carry 15 passengers with the maximum speed of 45 km/h. The trial, which is the first of its kind in Australia, will be initially conducted on private roads at RAC's driver centre then followed by tests on public roads upon obtaining government's approvals. The UWA REV Project has also developed robotic vehicle control technologies, including a self-driving Formula SAE racecar and a retrofitted semi-autonomous BMW X5 (UWA, 2016).

8. Concluding Comments

This review, while by no means comprehensive, indicates several key issues and unknowns if Australia is to embark on a journey to automation. First, while vehicle automation is a 'hot topic' and several 'trials' are being conducted both overseas and in Australia, there are clearly many unknowns and barriers around why, how and when this should happen. Second, technologically speaking, automation of vehicles itself is not a new concept with examples in other sectors, particularly rail. The difference here is that (unlike rail) and other instances where the environment can be constrained and controlled, roadways present a myriad of additional challenges for AVs to negotiate, particular within mixed traffic, pedestrians, cyclists etc. Third, we simply don't have the legislative or regulatory framework in place to deal with AVs and it is likely to lead to fundamental changes in liability models. Fourth, dialogue around AVs seems to be accompanied by dramatic changes in the way mobility will be provided in the future with the implicit assumption that vehicles will be used more efficiently, through shared models. Evidence suggests in Australia (and elsewhere) that breaking the 'love affair' with a personal vehicle and the control it offers, is likely to be a long, hard journey. Finally, if we look historically at road transport systems, inertia is a key feature and change happens very slowly. AVs may be coming, but there is a great deal of uncertainty around the timing.

9. References

ABC, 2016. *Canberra should be test site for driverless cars*, ACT Government says. ABC News, 8th of March, Available at: http://www.abc.net.au/news/2016-03-08/canberra-should-be-test-site-for-driverless-cars-act-government/7229524

Alessandrini, A., Campagna, A., Delle Site, P., Filippi, F., & Persia, L., 2015. Automated vehicles and the rethinking of mobility and cities. *Transportation Research Procedia,* 5, pp.145-160.

Alessandrini, A., Cattivera, A., Holguin, C., & Stam, D., 2014. CityMobil2: challenges and opportunities of fully automated mobility. In: *Road Vehicle Automation*. Springer International Publishing, pp.169-184.

Anderson, J.M., Kalra, N., Stanley, K.D., Sorensen, P., Samaras, O.A., & Oluwatola, C., 2016. *Autonomous Vehicle Technology: A Guide for Policymakers*, RAND .corporation. Available at http://www.rand.org/pubs/research_reports/RR443-2.html.

Arnaout, G.M.A. & Arnaout, J.-P.C., 2014. Exploring the effects of cooperative adaptive cruise control on highway traffic flow using microscopic traffic simulation. *Transportation Planning and Technology*, 37(2), pp.186–199.

Australian Government, 2016. *Smart Cities Plan*, Canberra, Australia. Available at: https://cities.dpmc.gov.au/smart-cities-plan.

Bazilinksy, P., Kyryakidis, M., & de Winter, J., 2015. An international crowdsourcing study into people's statements on fully automated driving. *Procedia Manufacturing, 3*, pp. 2534–2542.

Begg, D., 2014. *A 2050 vision for London: What are the implications of driverless transport?* Available at http://www.transporttimes.co.uk/reports.php.

Bert, J., Collie, B., Gerrits, M., and Xu G., 2016. *What's Ahead for Car Sharing? The New Mobility and Its Impact on Vehicle Sales*. Boston Consulting Group, Available at: http://www.bcg.de/documents/file206078.pdf

Carlson, M.S., Desai, M., Drury, J.L., Kwak, H., & Yanco, H.A., 2014. Identifying factors that influence trust in automated cars and medical diagnosis systems. In: *AAAI Symposium on the Intersection of Robust Intelligence and Trust in Autonomous Systems*, pp. 20–27. Available at: https://www.aaai.org/ocs/index.php/SSS/SSS14/paper/download/.../7725.

Castle, J., 2015. Car Sharing Services, Should you jump on the Bandwagon. *Choice Magazine Online*. Available at: https://www.choice.com.au/transport/cars/general/articles/car-sharing-vs-car-buying

Davis, L.C., 2004. Effect of adaptive cruise control systems on traffic flow. *Physical Review E*, 69(6), pp.66-110.

Davis, L.C., 2007. Effect of adaptive cruise control systems on mixed traffic flow near an on-ramp. *Physica A: Statistical Mechanics and its Applications*, 379(1), pp.274–290.

Daziano, R.A., Sarrias, M., & Leard, B., 2016. Are Consumers Willing to Pay to Let Cars Drive for Them? Analyzing Responses to Autonomous Vehicles. *Resources for the Future*, Discussion Paper, August 19, pp. 16-35.

Delbosc, A. & Currie, G., 2013. Causes of youth licensing decline: a synthesis of evidence. *Transport Reviews*, *33*(3), pp.271-290.

Delbosc, A. & Currie, G., 2014. Using discussion forums to explore attitudes toward cars and licensing among young Australians. *Transport Policy*, *31*(1), pp.27-34.

della Cava, M., 2016. Uber tests self-driving cars in Pittsburgh. *USA Today*. Available at: http://www.usatoday.com/story/tech/news/2016/05/19/uber-begins-testing-self-driving-cars-pittsburgh/84587848/ [Accessed May 20, 2016].

Dowling, R. & Kent, J., 2015. Practice and public–private partnerships in sustainable transport governance: The case of car sharing in Sydney, Australia. *Transport Policy*, 40, pp.58-64.

Dresner, K. & Stone, P., 2008. A multiagent approach to autonomous intersection management. *Journal of Artificial Intelligence Research*, 31, pp.591–656.

Fagnant, D. & Kockelman, K., 2015. Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research A*, 77, pp.167-181.

Fagnant, D.J. & Kockelman, K.M., 2014. The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research C*, 40, pp.1–13.

Firnkorn, J. & Müller, M., 2015. Free-floating electric carsharing-fleets in smart cities: The dawning of a post-private car era in urban environments? *Environmental Science & Policy*, *45*, pp.30-40.

Florin, R. & Olariu, S., 2015. A survey of vehicular communications for traffic signal optimization. *Vehicular Communications*, 2(2), pp.70–79.

Fraedrich, E. & Lenz, B., 2014. *Automated driving – individual and societal aspects entering the debate*. *Transportation Research Record*,, 2416, pp.64–72.

Galvin, P., 2016. QLD commits to building out driverless car strategy. *Tech Exec*. Available at: http://techexec.com.au/qld-commits-to-building-out-driverless-car-strategy/ [Accessed June 23, 2016].

Ge, J.I. & Orosz, G., 2014. Dynamics of connected vehicle systems with delayed acceleration feedback. *Transportation Research C*, 46, pp.46–64.

Gouy, M., Wiedemann, K., Stevens, A., Brunett, G., & Reed, N., 2014. Driving next to automated vehicle platoons: How do short time headways influence non-platoon drivers' longitudinal control? *Transportation Research Part F*, 27(B), pp.264–273.

Guler, I.S., Menendez, M. & Meier, L., 2014. Using connected vehicle technology to improve the efficiency of intersections. *Transportation Research C*, 46, pp.121–131.

Hillier, P., Wright, B. & Damen, P., 2014. *Readiness for Self-driving Vehicles in Australia*, Vermont South, Vic: ARRB Group Ltd. Available at: http://advi.org.au/wp-content/uploads/2016/04/Workshop-Report-Readiness-for-Self-Driving-Vehicles-in-

Australia.pdf

Horn, B.K.P., 2013. Suppressing traffic flow instabilities. In: *16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013)*. The Hague, The Netherlands: IEEE, pp.13–20.

Howard, D. & Dai, D., 2013. *Public Perceptions of Self-driving Cars: The Case of Berkeley, California*. 93rd Annual Meeting of the Transportation Research Board.

Kesting, A., Treiber, M., Schönhof, M., & Helbing., D., 2008. Adaptive cruise control design for active congestion avoidance. *Transportation Research C*, 16(6), pp.668–683.

Krueger, R., and Rashidi, T. & Rose, J., 2016. *Preferences for Shared Autonomous Vehicles*. Available at: http://ssrn.com/abstract=2770244 [accessed June 20, 2016].

Kyriakidis, M., Happee, R., & de Winter, J.C.F., 2015. Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research F*, 32, pp.127–140.

Le Vine, S., Zolfaghari, A. & Polak, J., 2015. Autonomous cars: The tension between occupant experience and intersection capacity. *Transportation Research C*, 52, pp.1–14.

Li, Z., Chitturi, M., Zheng, D., Bill, A. & Noyce, D., 2013. Modeling reservation-based autonomous intersection control in VISSIM. *Transportation Research Record*, 2381, pp.81–90.

Liang, C.-Y. & Peng, H., 2000. String stability analysis of adaptive cruise controlled vehicles. *JSME International Journal Series C*, 43(3), pp.671–677.

Lu, Q. & Kim, K., 2016. Intelligent intersection management of autonomous traffic using discrete-time occupancies trajectory. *Journal of Traffic and Logistics Engineering*, 4(1), pp.1–6.

Madigan, R., Louw, T., Dziennus, M., Graindorge, T., Ortega, E., Graindorge, M., & Merat, N., 2016. Acceptance of Automated Road Transport Systems (ARTS): An adaptation of the UTAUT model. Proceedings of the *6th Transport Research Area*, Warsaw, Poland: April, pp.18–21.

McKinsey & Company, 2016. *Automotive revolution – perspective towards 2030*. Available at:http://www.mckinsey.com/~/media/mckinsey/industries/high%20tech/our%20insights/disruptive%20trends%20that%20will%20transform%20the%20auto%20industry/auto%202030%20report%20jan%202016.ashx.

NHTSA, 2013. *Preliminary statement of policy concerning automated vehicles*, Washington, DC. Available at: www.nhtsa.gov.

NTC, 2016a. *Regulatory barriers to more automated road and rail vehicles: Issues paper*, Melbourne. Available at: http://www.ntc.gov.au/Media/Reports/(66E42530-B078-4B69-A5E3-53C22759F26E).pdf

NTC, 2016b. *Regulatory options for automated vehicles: Annex*, Melbourne. Available at: http://www.ntc.gov.au/Media/Reports/(264DF9EA-6247-42C9-8D07-F39E76E95258).pdf.

NTC, 2016c. *Regulatory options for automated vehicles: Executive summary*, Melbourne. Available at: http://www.ntc.gov.au/Media/Reports/(80E9EBF1-53F0-44F7-96CF-07D60A324122).pdf.

Orosz, G. & Stépán, G., 2006. Subcritical Hopf bifurcations in a car-following model with reaction-time delay. Proceedings of the *Royal Society of London A: Mathematical, Physical and Engineering Sciences*, 462(2073), pp.2643–2670.

Payre, W., Cestac, J., & Delhomme, P., 2014. Intention to use a fully automated car: Attitudes and a priori acceptability. *Transportation Research F*, 27, pp.252-263.

Petit, J. & Shladover, S.E., 2015. Potential Cyberattacks on Automated Vehicles. *IEEE Transactions on Intelligent Transportation Systems*, 16(2), pp.546–556.

RAC 2016. RAC driverless shuttle bus in Australian-first trial. *RAC eNews*. Available at: http://rac.com.au/news-community/news-and-reports/publications/rac-enews/rac-enews-2016/rac-driverless-bus-first-trial [Accessed June 23, 2016].

Retter, P., 2016. The 716 rules blocking driverless cars. *WA Today*. Available at: http://www.watoday.com.au/business/consumer-affairs/the-716-rules-blocking-driverless-cars-20160509-gopyoa.html [Accessed May 12, 2016].

SAE International, 2014. *International Standard J3016 Taxonomy and Definitions for Terms related to On-Road Motor Vehicle Automated Driving Systems*. Available at: www.sae.org/autodrive.

Schoettle, B. & Sivak, M., 2014a. *A survey of public opinion about autonomous and self-driving vehicles in the U.S., the U. K., and Australia* (Report UMTRI-2014-21), The University of Michigan Transportation Research Institute. Available at: https://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf?sequence=1&isAllowed=y.

Schoettle, B. & Sivak, M., 2014ab. *Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia* (Report UMTRI-2014-30), The University of Michigan Transportation Research Institute. Available at: https://deepblue.lib.umich.edu/bitstream/handle/2027.42/109433/103139.pdf?seque.

Schoettle, B. & Sivak, M., 2015a. *Motorists' Preferences for Different Levels of Vehicle Automation* (Report UMTRI-2015-22), The University of Michigan Transportation Research Institute. Available at: https://deepblue.lib.umich.edu/bitstream/handle/2027.42/114386/103217.pdf.

Schoettle, B. & Sivak, M., 2015b. *Potential impact of self-driving vehicles on household vehicle demand and usage* (Report UMTRI-2015-3), The University of Michigan Transportation Research Institute. Available at: https://deepblue.lib.umich.edu/bitstream/handle/2027.42/110789/103157.pdf?sequence=1&isAllowed=y.

Shladover, S.E., 2009. Cooperative (rather than autonomous) vehicle-highway automation systems. *IEEE Intelligent Transportation Systems Magazine*, 1(1), pp.10–19.

Shoup, D., 2005. *The High Cost of Free Parking*, Updated Edition, Planners Press, U.S.A.

Sommer, K., 2013. *Continental mobility study 2013*. Available at http://www.continental-corporation.com/www/download/pressportal_com_en/themes/initiatives/channel_mobility_study_en/ov_mobility_study2013_en/download_channel/pres_mobility_study_en.pdf.

Sun, Y., Gladstone, L., Taplin, J., 2016. Hype or hope – can future transport technologies ease congestion? In: Biermann, S., Olaru, D. and Paul, V. (eds.), *Planning Boomtown and Beyond. Perth, Australia*: UWA Publishing (in press).

Tachet, R., Santi, P., Sobolevsky, S., Reyes-Castro, L. I., Frazzoli, E., Helbing, D., & Ratti, C., 2016. Revisiting street intersections using slot-based systems. *Plos One*, 11(3), p.e0149607. Available at: http://dx.plos.org/10.1371/journal.pone.0149607.

Tranter., K., 2016. The challenges of autonomous motor vehicles for Queensland road and criminal laws. *QUT Law Review*, 16(2), pp.59–81.

Trimble, T.E., Bishop, R., Morgan, J.F., & Blanco, M., 2014. Human Factors Evaluation of

Levels 2 and 3 Automated Driving Concepts: Past Research, State of Automation Technology, and Emerging System Concepts. In: Reeves, J. (Ed.) *Human Factors in Automated Driving Scenarios*. USA: Nova Science Publishers, Inc., pp.2-94.

Tucker, H., 2016. South Australia has just legalised driverless cars. *Business Insider Australia*. Available at: http://www.businessinsider.com.au/south-australia-has-just-legalised-driverless-cars-2016-4

Underwood, S.E., 2014. Automated vehicles forecast vehicle symposium opinion survey. Presented at the *2014 Automated Vehicles Symposium*, San Francisco, USA, July 15-17. Available at: https://higherlogicdownload.s3.amazonaws.com/AUVSI/3a47c2f1-97a8-4fb7-8a39-56cba0733145/UploadedFiles/AVS%202014%20Proceedings%20-%20Final%20(Dec%202014).pdf.

UNSW, 2014. *Working with industry on a 'self-driving' car*. UNSW Newsroom. Available at: http://newsroom.unsw.edu.au/news/technology/working-industry-self-driving-car [Accessed June 23, 2016].

UWA, 2016. *The REV Project*. Available at: http://revproject.com/ [Accessed June 23, 2016].

VanderWerf, J., S. E. Shladover, M. A. Miller, & Kourjanskaia, N., 2003. Evaluation of the Effects of Adaptive Cruise Control Systems on Highway Traffic Flow Capacity and Implications for Deployment of Future Automated Systems. *81st Annual Meeting of the Transportation Research Board*, Washington, DC, pp.78–84.

van Nunen, E., Kwakkernaat, M. R. J. A. E., Ploeg, J., & Netten, B. D., 2012. Cooperative Competition for Future Mobility. *IEEE Transactions on Intelligent Transportation Systems*, 13(3), pp.1018–1025.

Victoria State Government, 2016. *Intelligent Transport Grants Now Open*. Media Release. Available at: http://www.premier.vic.gov.au/intelligent-transport-grants-now-open/ [Accessed June 23, 2016].

Washington, S., Aminmansour, S., Zheng, Z., & Whitehead, J., 2016. *The impact of car sharing and self-driving vehicles on future mobility: Why governments and mobility providers should pay attention*. Brisbane: Queensland University of Technology. Available at: https://optreviewqld.com.au/about-the-review/documents/33171/download.

Wight, V.R., Raley, S.B., & Bianchi, S.M., 2009. Time for Children, One's Spouse and Oneself among Parents Who Work Nonstandard Hours. *Social Forces*, 87(1), pp.243-271.

Zhang, L. & Orosz, G., 2013. Designing network motifs in connected vehicle systems: delay effects and stability. In *Proceedings of the ASME 2013 Dynamic Systems and Control Conference*. Palo Alto, California, USA: ASME - The American Society of Mechanical Engineers, pp. V003T042A006–V003T042A006.

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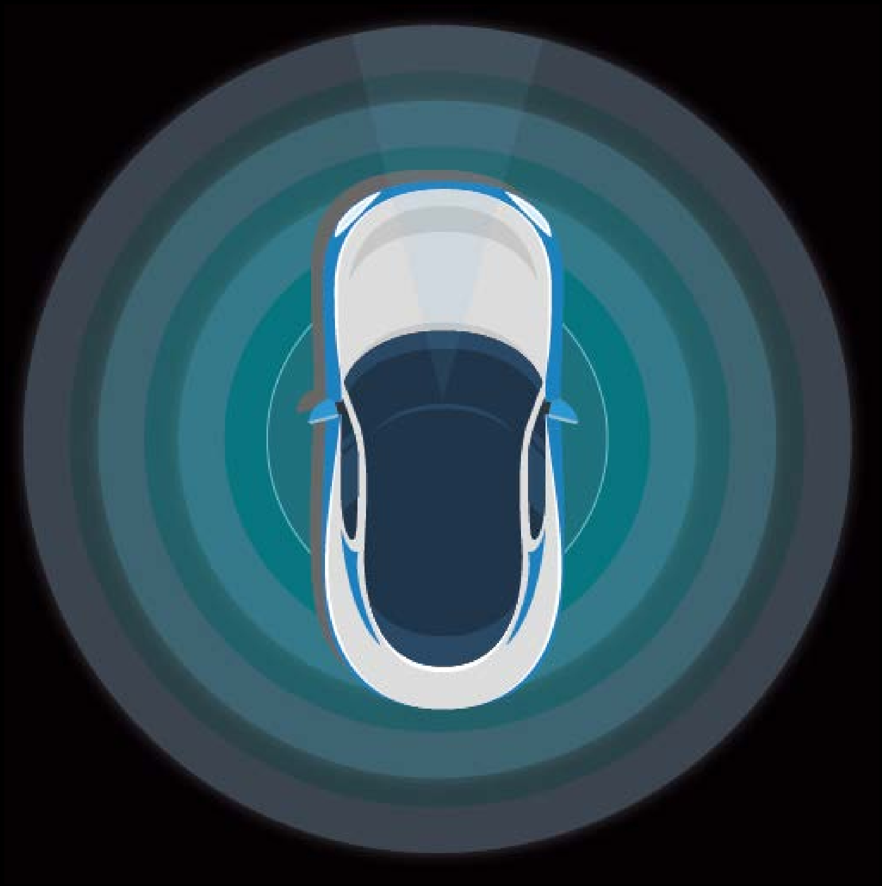


What's ahead for fully autonomous driving

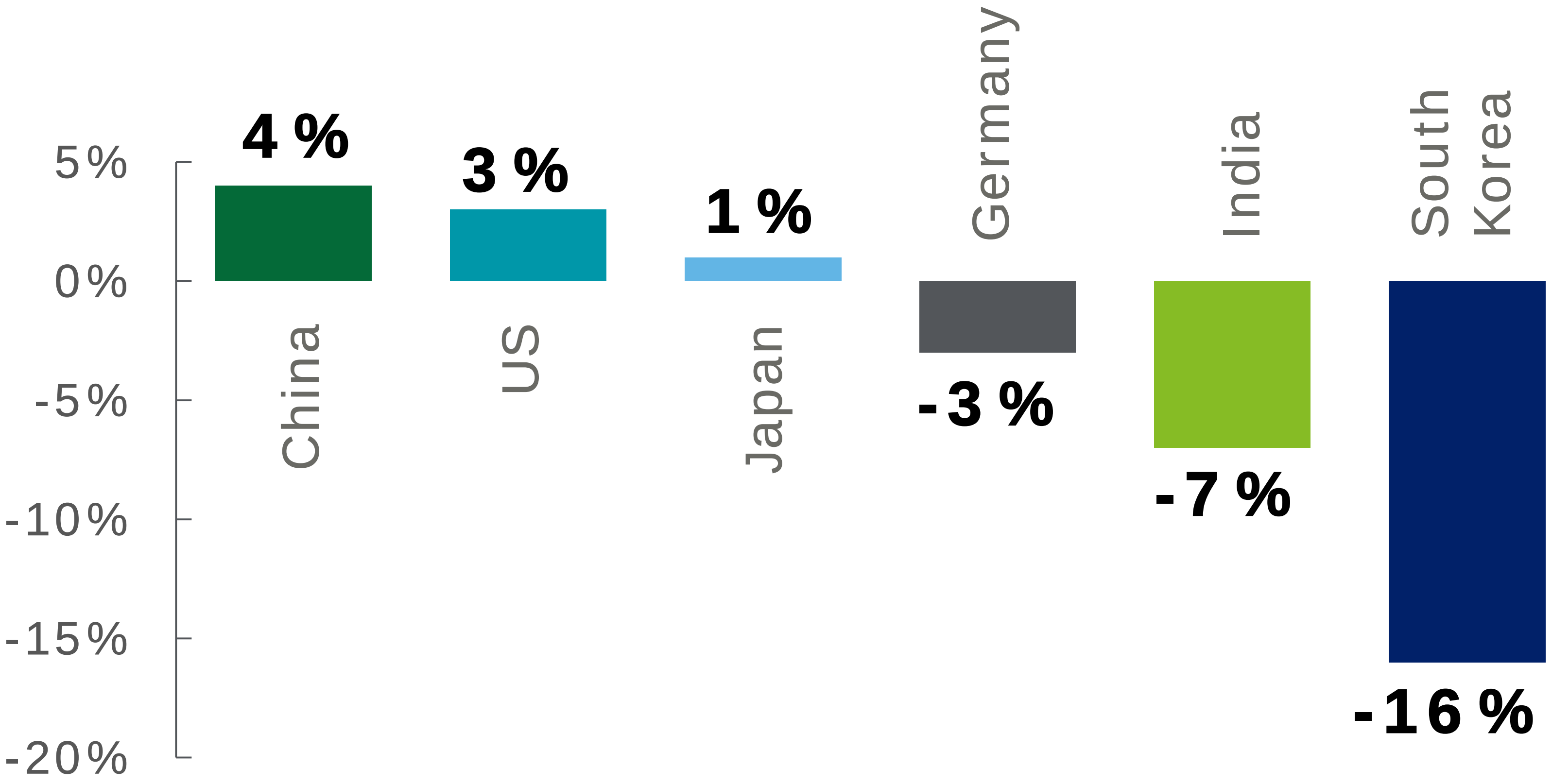
Consumer opinions on advanced vehicle technology

Deloitte Global Automotive Consumer Study

January 2017

Deloitte.

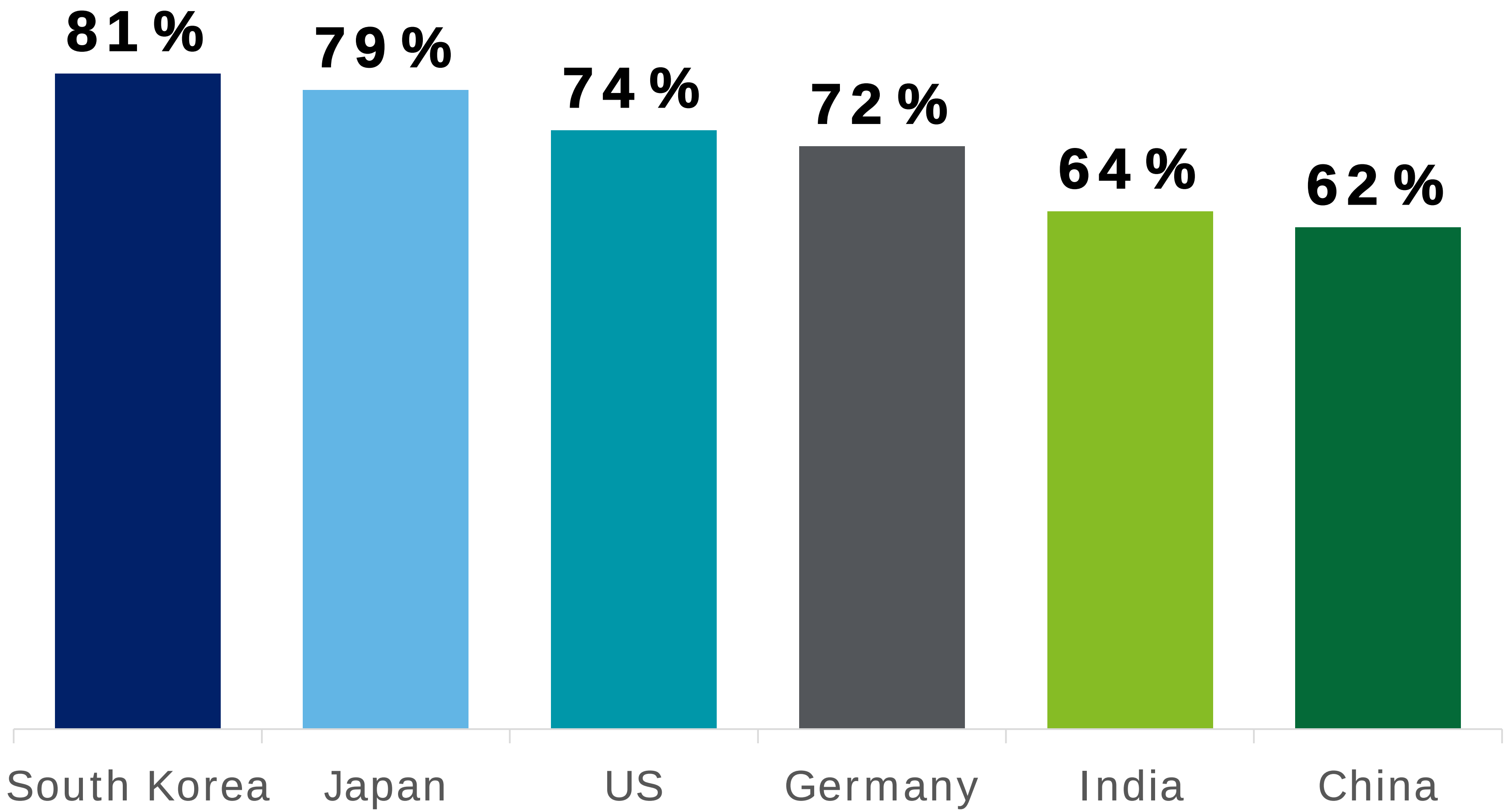
Change in desirability for fully autonomous vehicles since 2014



Source: Global Automotive Consumer Study

Deloitte.

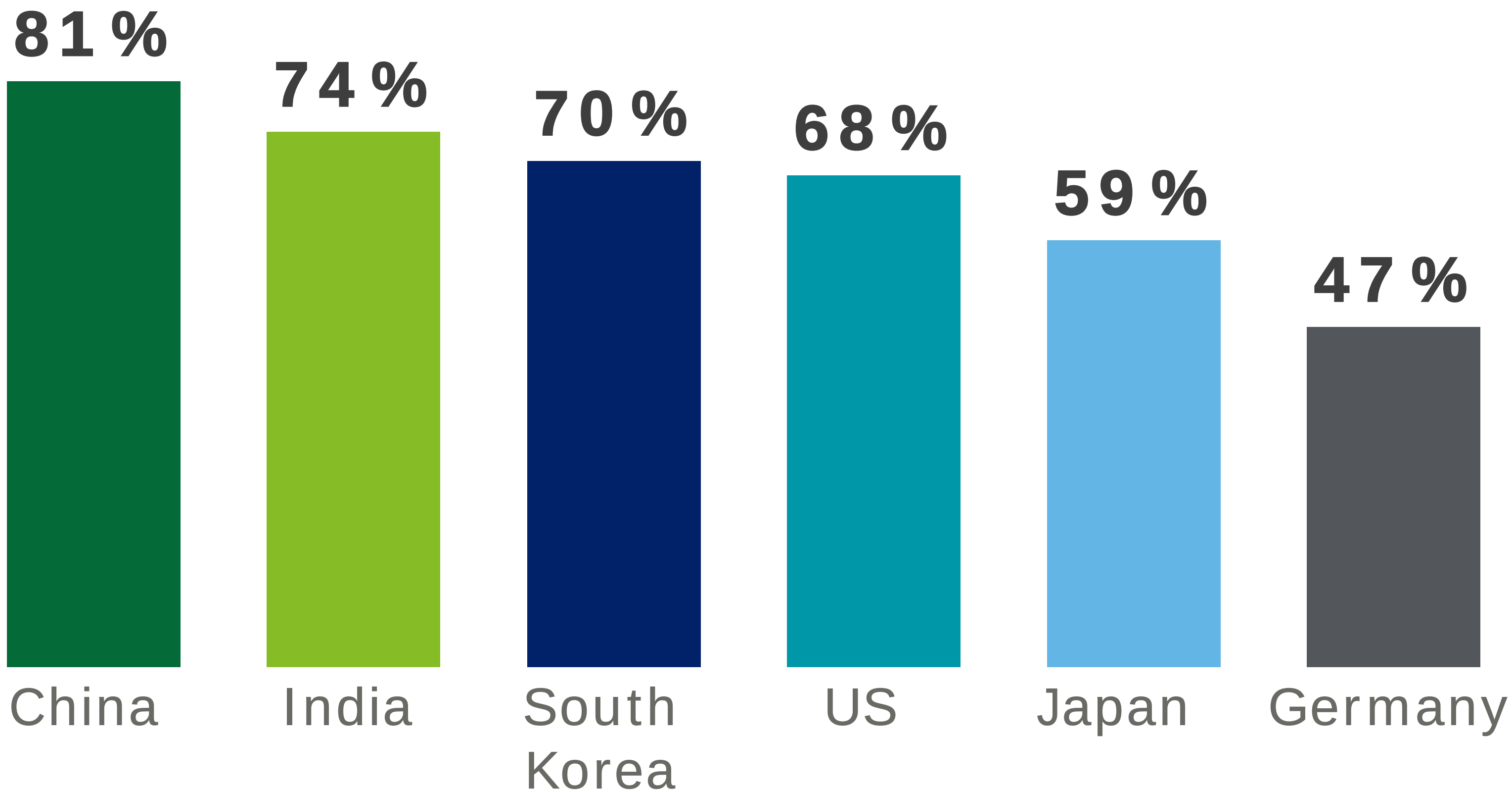
Percentage of consumers who feel fully autonomous vehicles will ***NOT*** be safe



Source: Global Automotive Consumer Study

Deloitte.

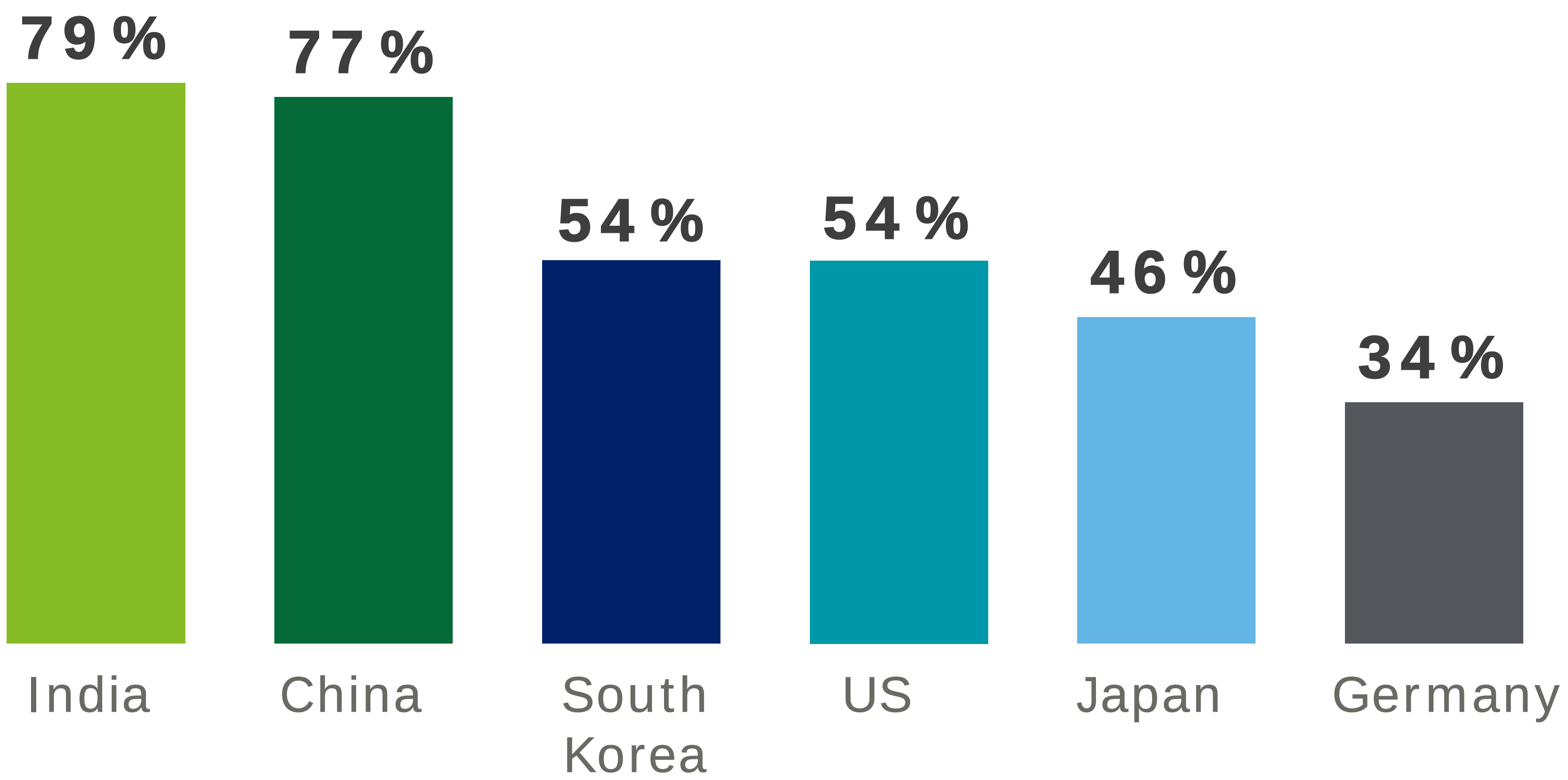
Percentage of consumers who feel an established track record of fully autonomous cars being safely used would make them more likely to ride in one



Source: Global Automotive Consumer Study

Deloitte.

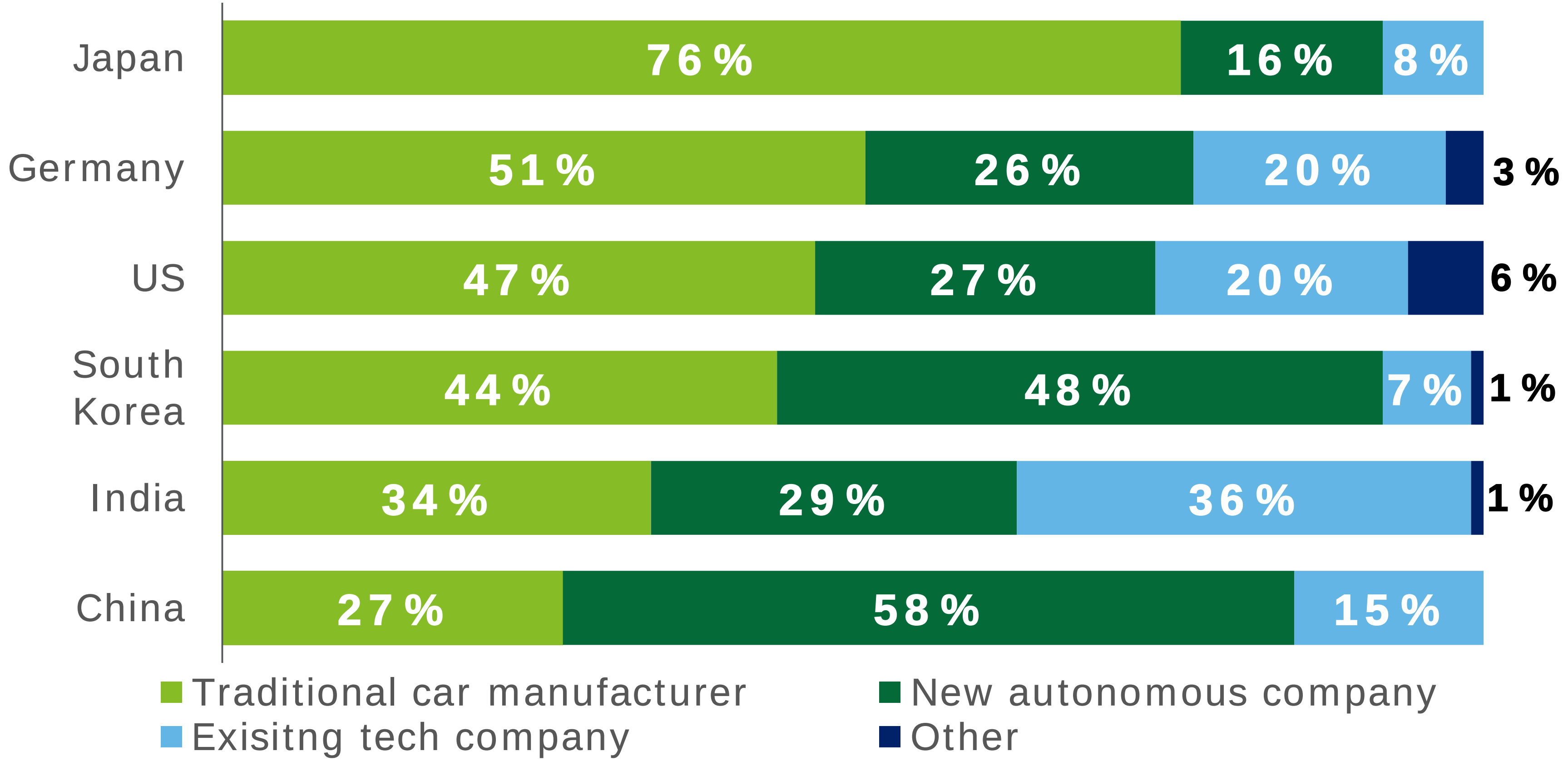
Percentage of consumers who feel they would be more likely to ride in a fully autonomous vehicle if it were offered by a brand they trust



Source: Global Automotive Consumer Study

Deloitte.

Types of companies consumers trust most to bring fully autonomous vehicles to market



Source: Global Automotive Consumer Study

Deloitte.

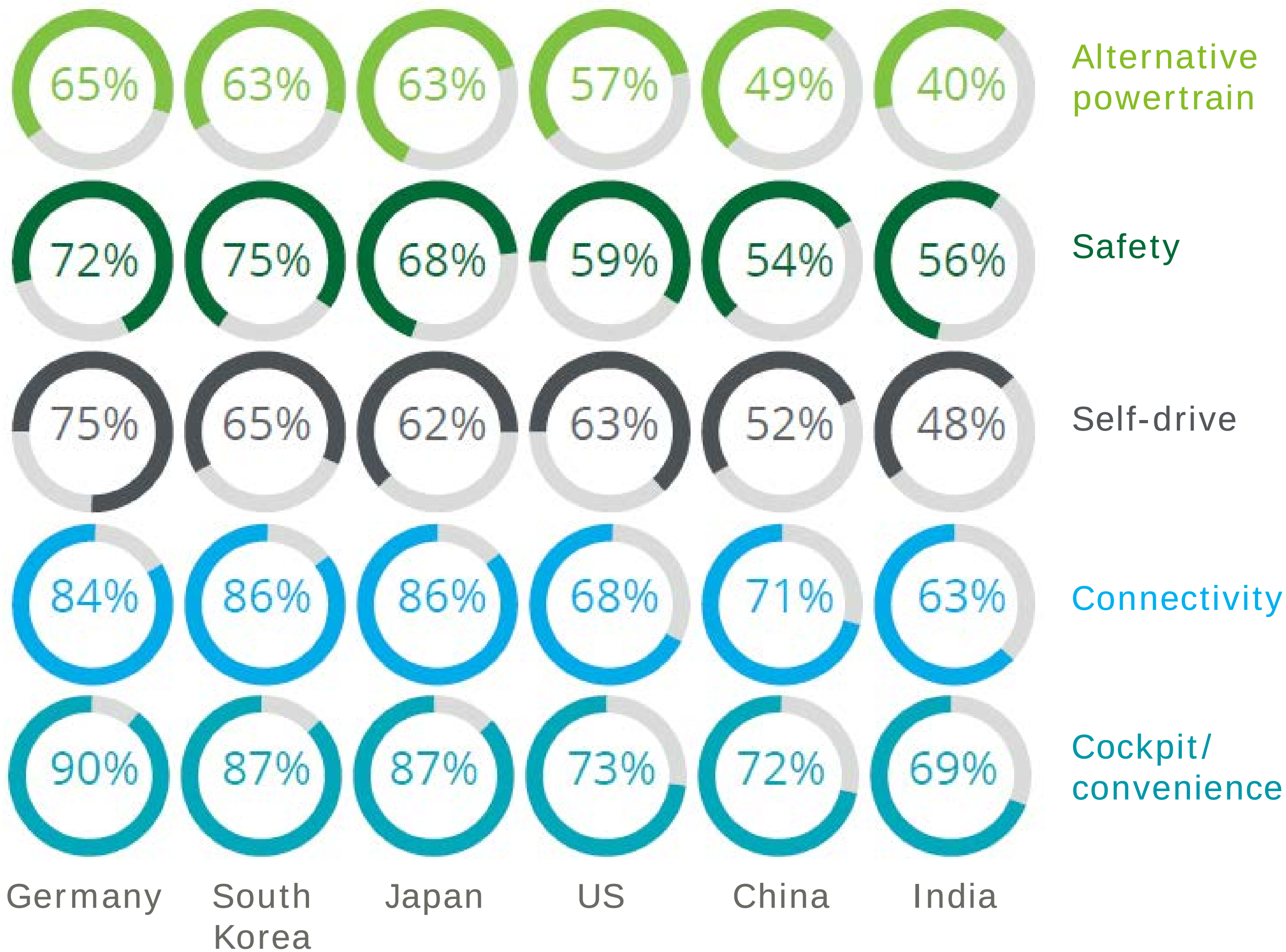
Consumers' most and least preferred advanced automotive technologies

Description	Category	US	Germany	Japan	South Korea	China	India
Recognizes objects on road and avoids collision	Safety	1	1	1	2	1	1
Informs driver of dangerous driving situations	Safety	2	3	4	3	3	4
Blocks driver from dangerous driving situations	Safety	3	2	2	1	2	2
Takes steps in medical emergency or accident	Safety	4	4	3	4	4	3
Diagnoses and sends maintenance notifications	Connectivity	5	14	12	5	6	5
Enables remote shutdown of stolen vehicle	Cyber security	6	13	8	14	8	8
Helps enhance fuel efficiency	Fuel efficiency	7	5	6	11	12	7
Enables vehicles-to-vehicle and road communication	Connectivity	8	10	5	9	5	11
Prevents hacking into vehicle systems	Cyber security	9	15	19	17	22	13
Prevents theft by restricting unauthorized access	Cyber security	10	7	16	20	18	10
Enables use of advanced lightweight materials	Fuel efficiency	11	11	14	12	7	12
Enables interactive vehicle operational information	Convenience	12	16	18	19	20	17
Enables usage of alternative fuels	Environment	13	6	9	6	11	6
Automates tasks for comfort and convenience	Convenience	14	12	10	7	9	14
Lowers the impact on the environment	Environment	15	8	15	13	16	9
Enables hands-free interior controls	Convenience	16	23	26	30	29	24
Monitors the physical health of the driver	Safety	17	9	13	16	13	15
Enables high-speed, long-distance, highway “auto-pilot” mode	Self-drive	18	17	11	8	15	19
Enables remote/automatic software updates of the vehicle	Connectivity	19	25	24	21	31	22
Allows use of smartphone applications through the vehicle dashboard	Connectivity	20	28	32	29	27	26
Enables full self-driving capabilities	Self-drive	21	20	7	10	14	20
Coaches the driver to drive safely	Cost efficiency	22	18	17	18	10	16
Makes available adjustable settings to enhance vehicle performance	Performance*	23	21	20	15	23	18
Assists in locating, reserving, and navigating to a parking space	Service enabler	24	19	25	25	17	21
Enables the use of self-healing paint	Miscellaneous	25	24	23	27	25	32
Provides passengers with customized entertainment while driving	Convenience	26	32	30	28	30	28
Provides notifications when places of interest are near	Service enabler	27	26	31	31	26	23
Automatically pays parking and toll fees	Service enabler	28	27	22	26	21	30
Empowers customer to personalize vehicles	Miscellaneous	29	30	28	22	28	27
Allows the driver to control automated home systems	Service enabler	30	29	29	24	24	29
Enables low-speed urban “auto pilot” mode	Self-drive	31	22	21	23	19	25
Helps manage daily activities	Convenience	32	31	27	32	32	31

Source: Global Automotive Consumer Study

Deloitte.

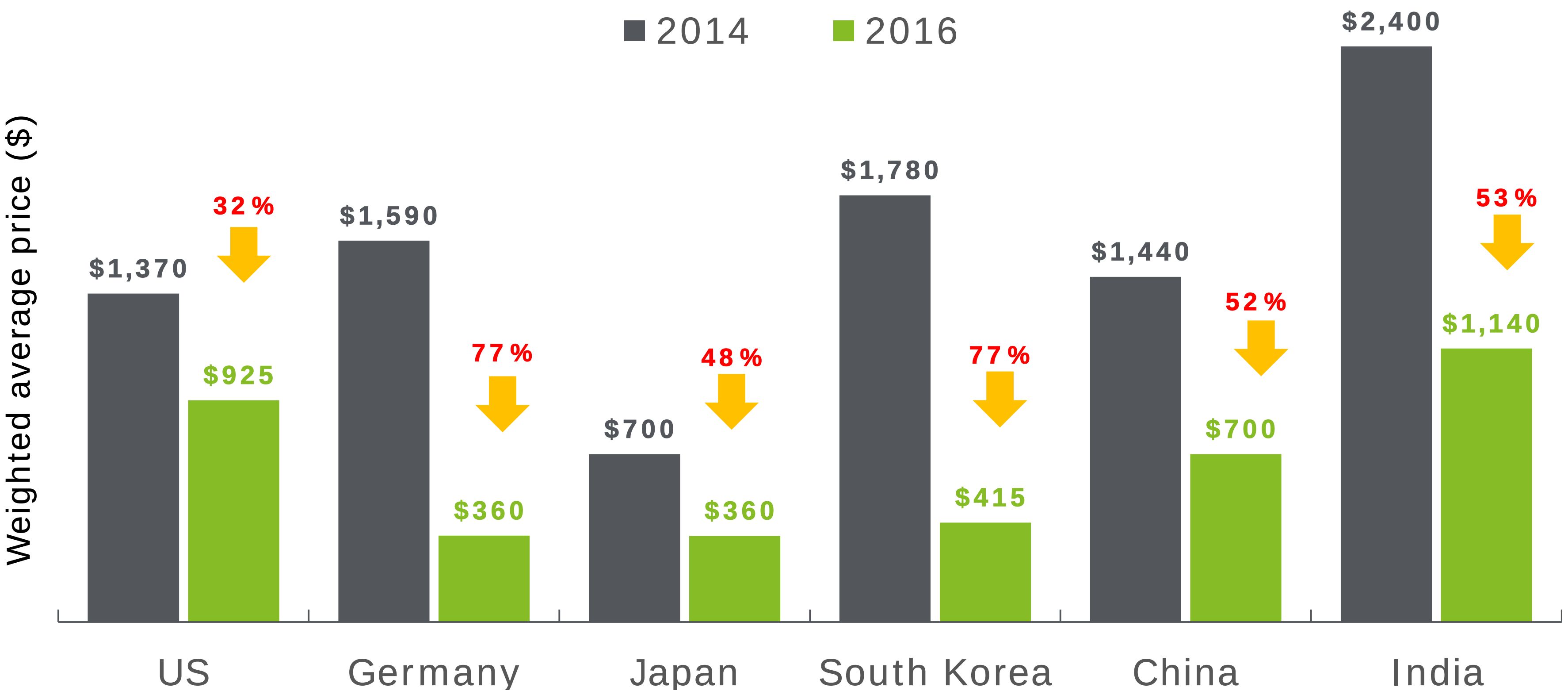
Percentage of consumers who are ***NOT*** willing to pay more than $500 for various advanced vehicle technologies



Source: Global Automotive Consumer Study

Deloitte.

Overall expected price which consumers are willing to pay for advanced automotive technologies (2014 and 2016)

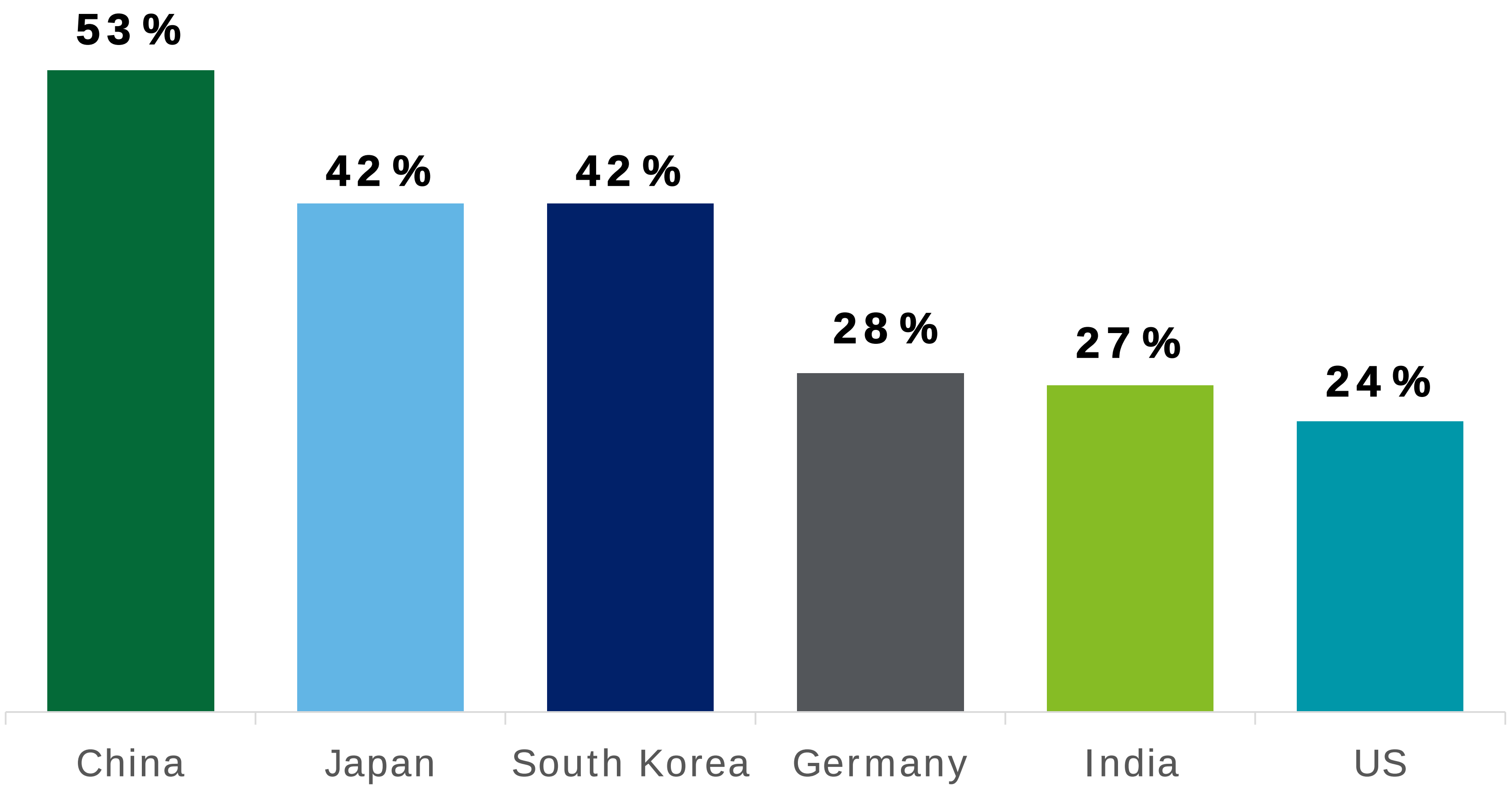


The $ value for each country represents the average of overall weighted prices across the five technology categories, that is, safety, connectivity, cockpit/convenience, self-drive, and alternative engines. The non-USD currency has been converted into USD by using the average exchange rates in 2016

Source: Global Automotive Consumer Study

Deloitte.

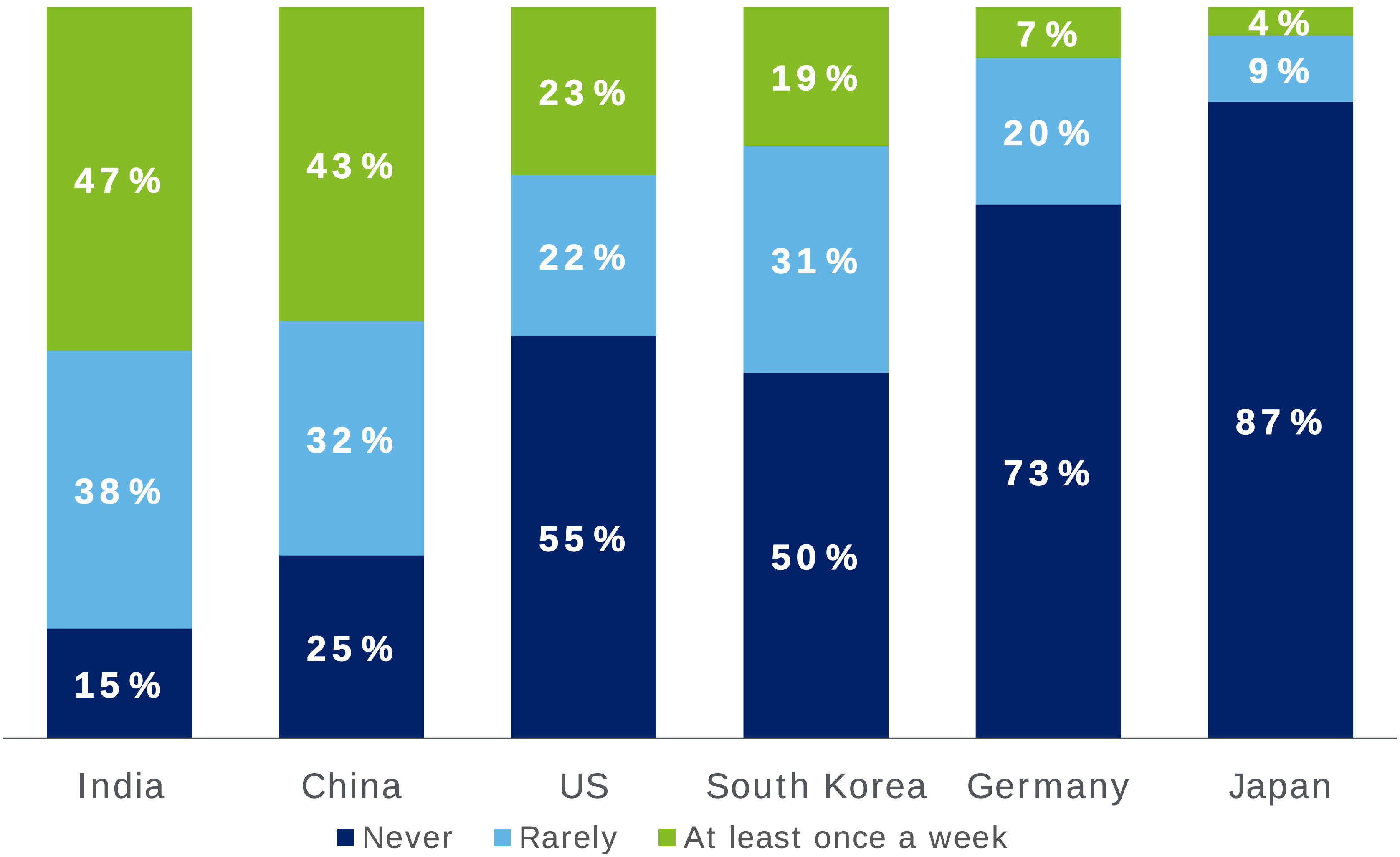
Percentage of consumers who would prefer a hybrid-electric, battery-electric or other form of alternative powertrain in their next vehicle



Source: Global Automotive Consumer Study

Deloitte.

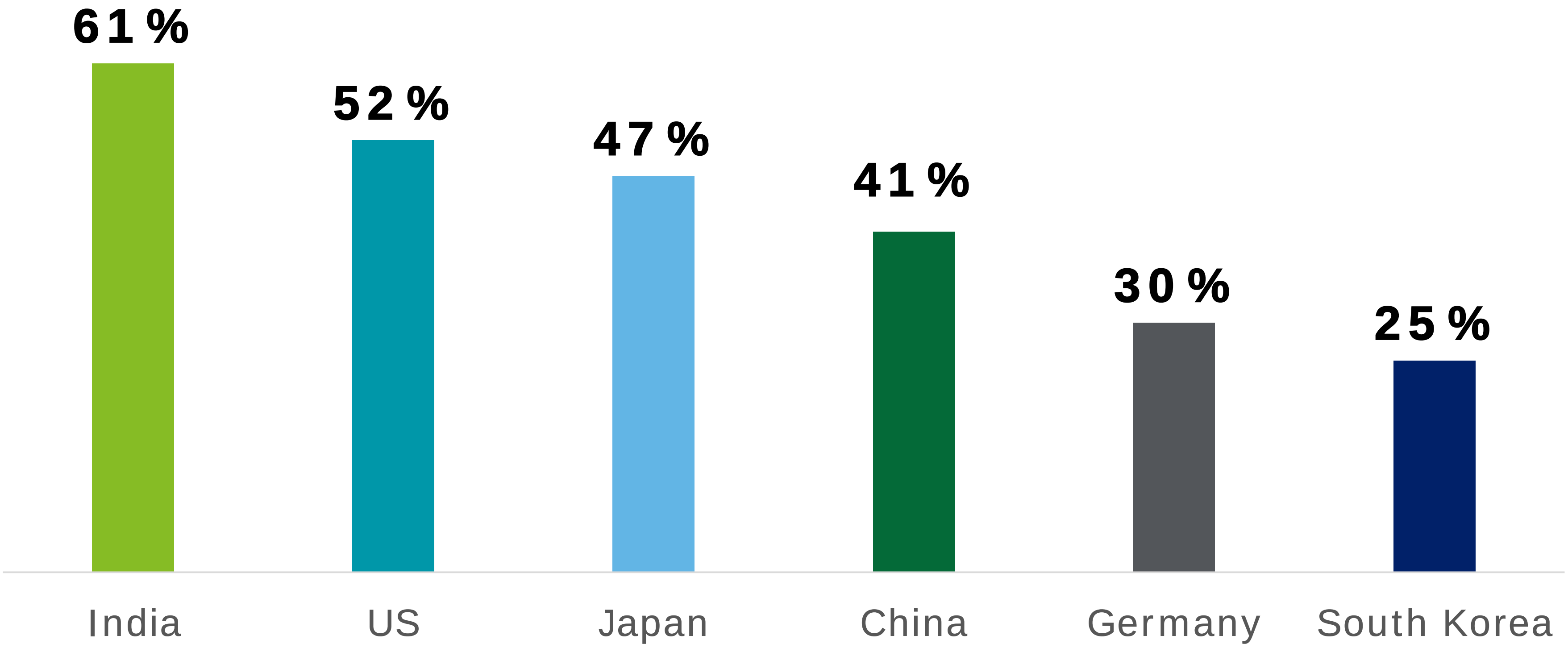
Frequency that consumers use ride-hailing services, by country



Source: Global Automotive Consumer Study

Deloitte.

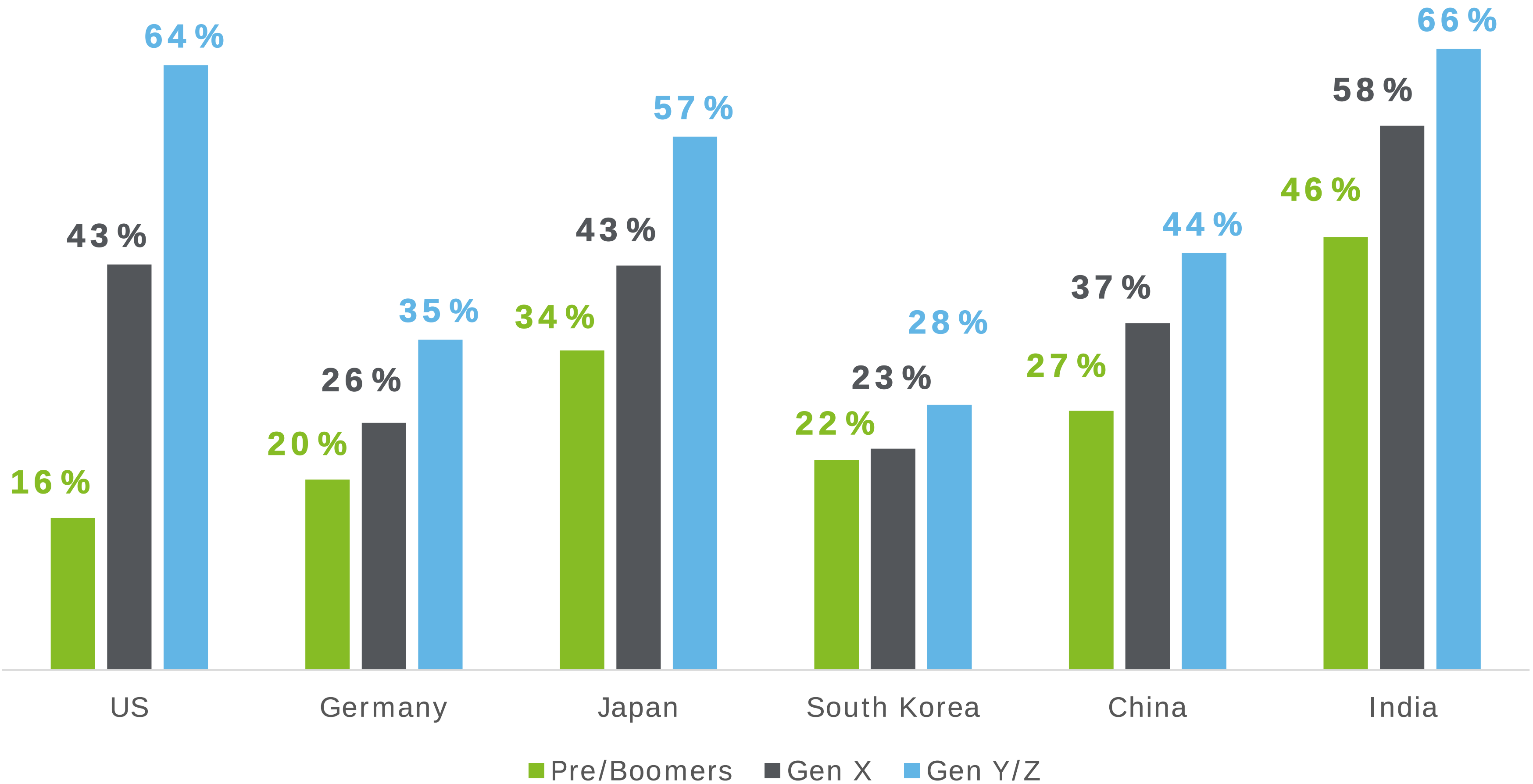
Percentage of consumers who use ride-hailing services and question their need to own a vehicle in the future



Source: Global Automotive Consumer Study

Deloitte.

Percentage of consumers who use ride-hailing services and question their need to own a vehicle in the future, by generation

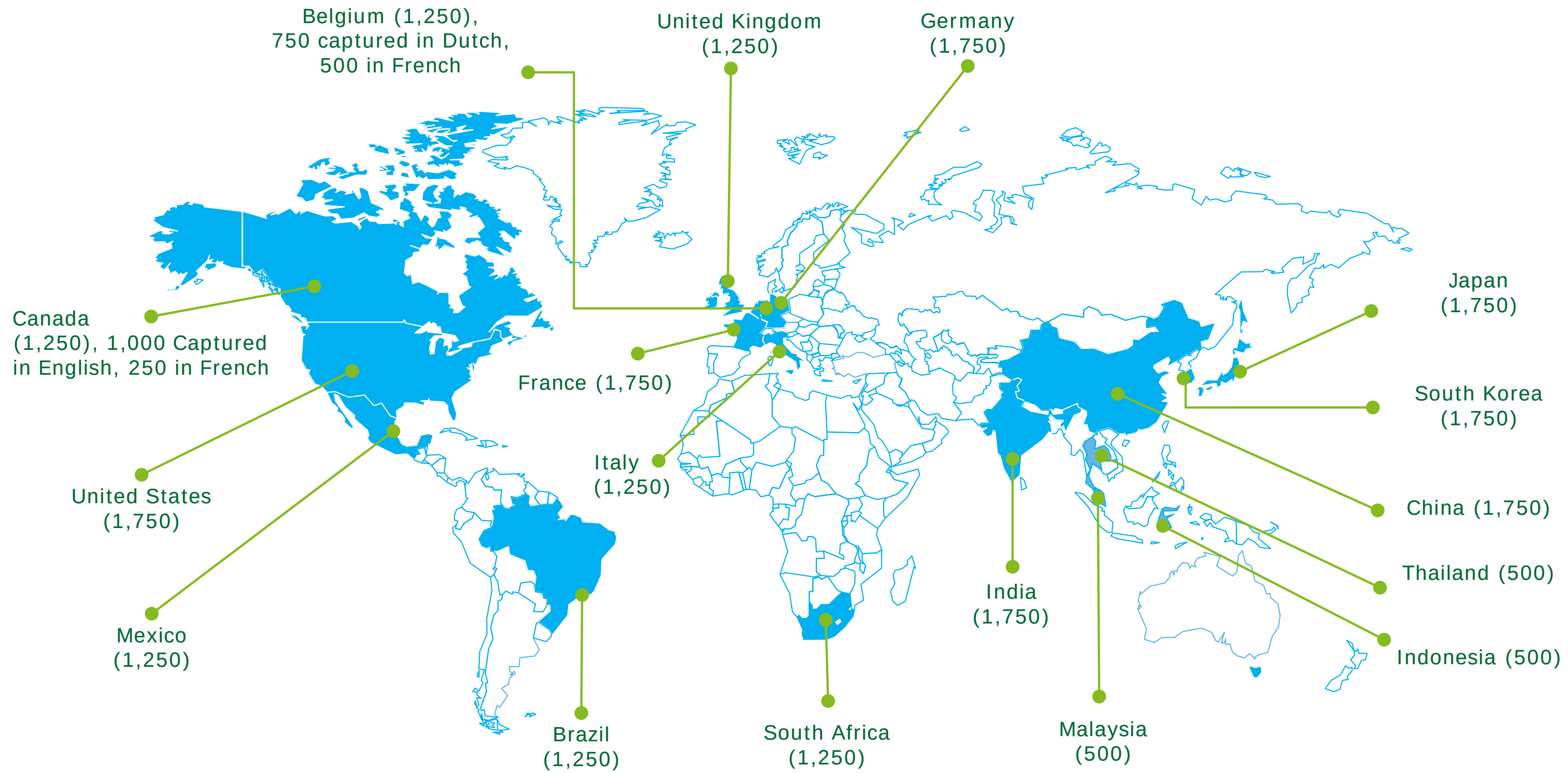


Source: Global Automotive Consumer Study

About the Global Automotive Consumer Study

Deloitte.

The Global Automotive Consumer Study surveyed over 22,000 consumers in 17 countries around the world



Source: Global Automotive Consumer Study

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NISSAN

Innovation that excites

NISSAN FUTURES

The Nissan Social Index

Consumer Attitudes to Autonomous Drive

Future... a small word with a huge number of theories, possibilities and opportunities revolving all around it

People have been dreaming about what the future of the car would look like since we moved from four legs to four wheels as our primary mode of transport. From jet-powered speed racers to flying DeLoreans, from cartoon rockets to the talking corvette with a mind of its own...many have dreamed of what this breakthrough intelligent vehicle would look like, what it could do, and perhaps most importantly, what it would mean for us as drivers, consumers and human beings.

The dreaming at Nissan began over a decade ago, just after the turn of the millennium, when a team of Research & Development engineers were tasked with a new project to create a vehicle that can drive itself. It must have sounded like science fiction. But then, before the invention of the car, so did the ability to travel from town to town in a matter of minutes.

Today, as we are well aware, the stuff of science fiction is fast becoming solid scientific fact. From the quantum leaps of Quantum Physics to the discovery of ultra-light, ultra-tough new materials such as graphene, the pace of change in scientific discovery is transforming our world.

This is why we are pleased to unveil the results of what we believe is the most comprehensive analysis of attitudes towards the future of driving that has ever been undertaken.

The future of mobility is one of immense possibility, innovation and excitement for all, and that's why we believe this study is so important. It marks an important snapshot in time that distils the interest, excitement, and questions that the European consumer of the early 21st century has about one of the world's most ground-breaking technological advances.

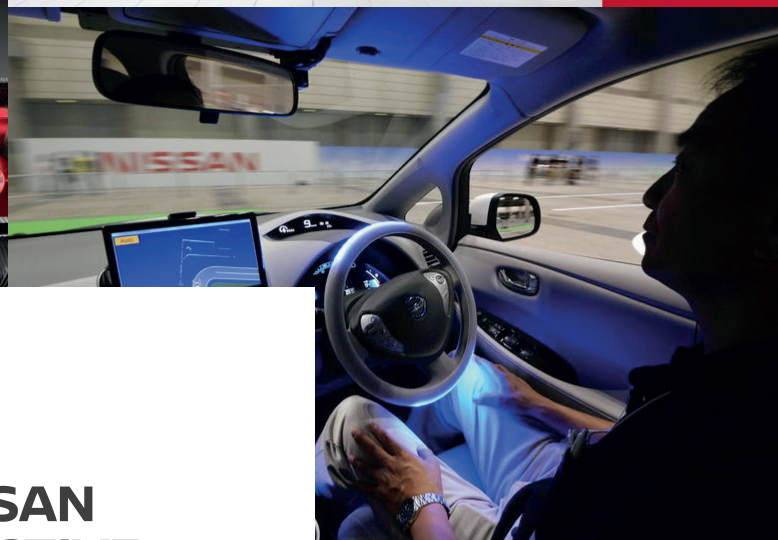
The results of this report will continue to help us shape the way we educate consumers about Nissan Intelligent Mobility – our vision of the future which encompasses the way people drive, how they power their cars, and how our inventions will integrate into the wider world.

We hope you find it insightful and interesting.

Paul Willcox
Chairman, Nissan Europe

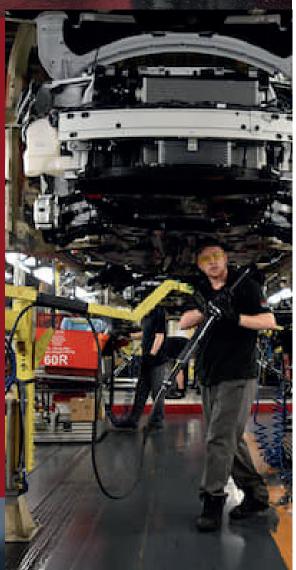
P. Willcox

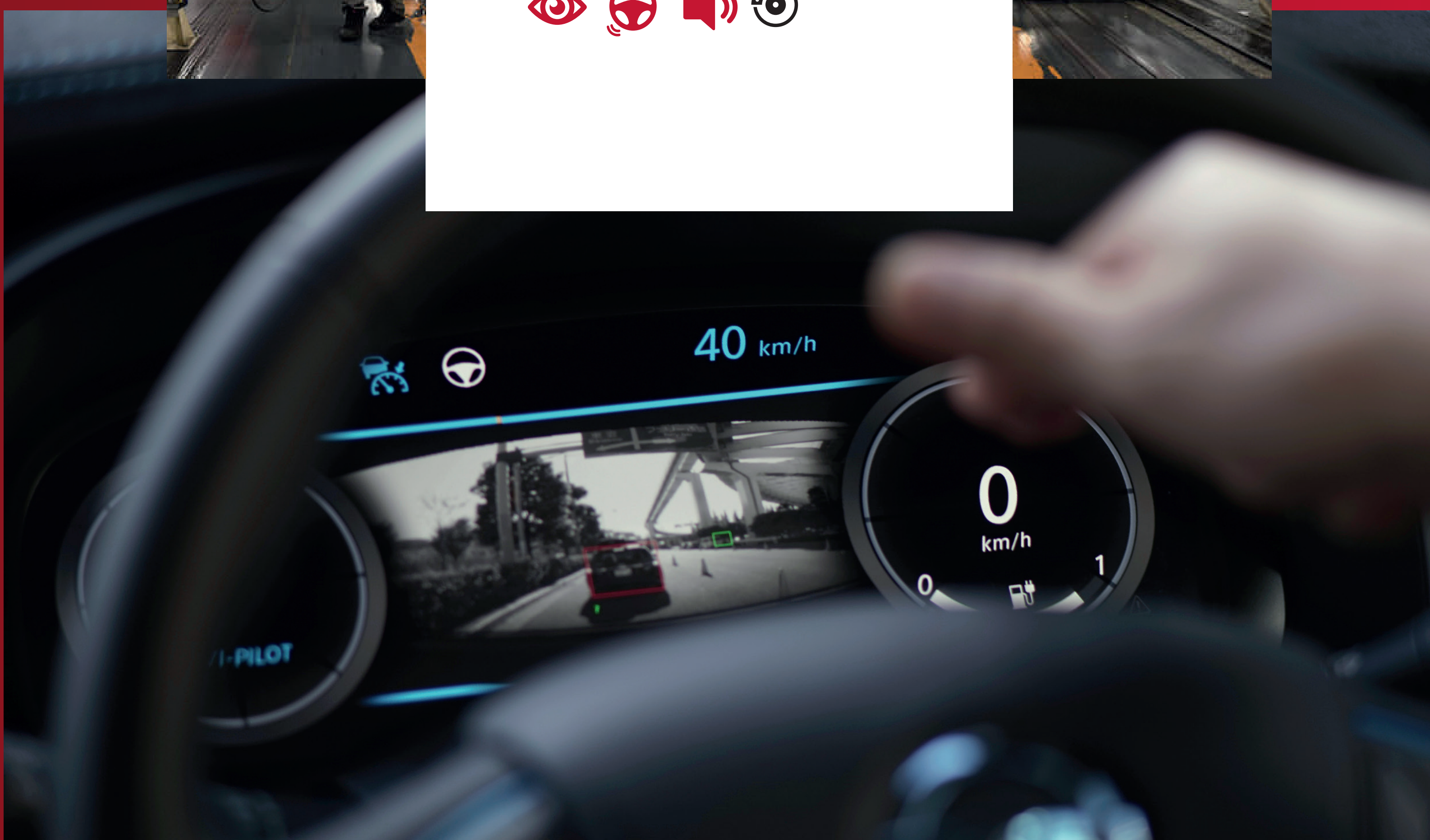
"Now that's Nissan Intelligent Mobility."

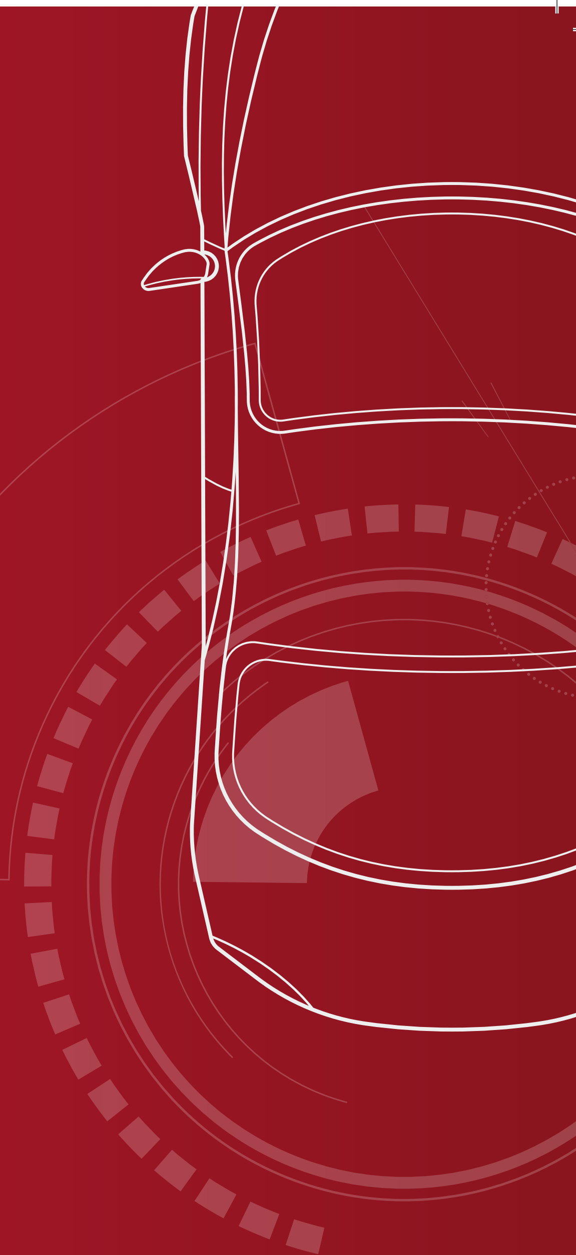


THE NISSAN PERSPECTIVE
INTELLIGENT MOBILITY

At Nissan, we are focused on providing accessible autonomous drive technologies that will help to build a cleaner, safer and smarter future for everyone.







As a responsible, progressive automaker, we're not only interested in making real improvements to people's lives now, but we remain in pursuit of a cleaner, safer world for future generations to come. We believe a zero emission zero fatality future is an achievable goal, not a pipedream.

To achieve this goal, we're focused on three core areas of innovation: how cars are powered, how they are integrated into society and how they are driven. This is what we at Nissan call Nissan Intelligent Mobility – an approach to designing and building cars that is our roadmap for the future. A future where driving is intelligent.

Through Nissan Intelligent Mobility, we are building a better future for people everywhere. A future that is distinctly more confident, more exciting and more connected. A future that delivers on our promise of Innovation and Excitement for Everyone.

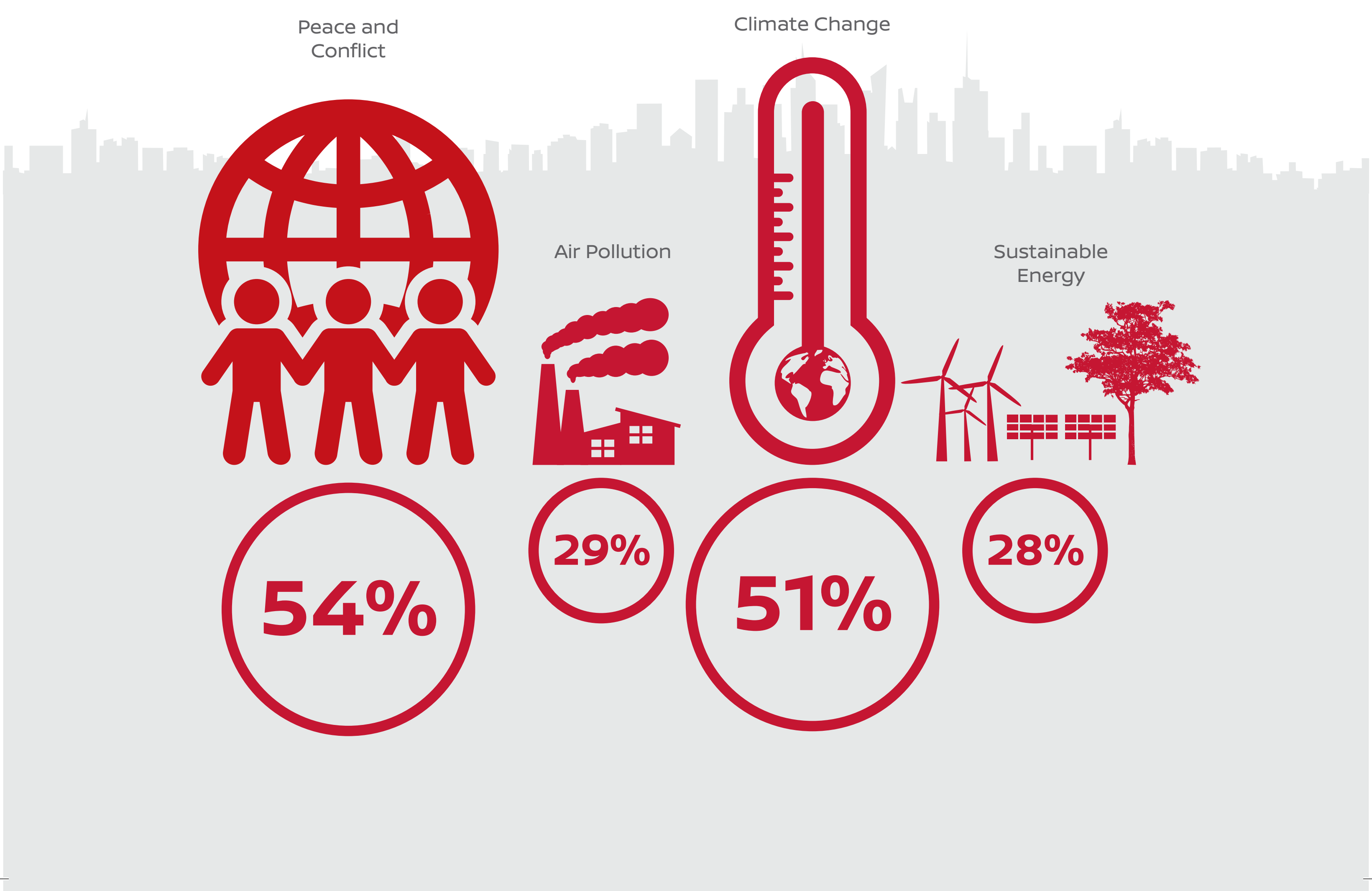
The benefits of this Intelligent Driving vision are clear:

- Improving safety by helping the driver to see, think, and react fast
- Improving the driving experience through increased safety, control and comfort
- Improving access by ensuring everyone can benefit from these technologies

THE ROLE OF TECHNOLOGY AND INNOVATION IN TODAY'S SOCIETY

There is no question that the pace of innovation and change is moving more quickly than at any other time in our history. Innovations and technology that were considered science fiction just 20 years ago have now become the norm of everyday life, from video calling, to connected devices that monitor and optimise our health, to green and renewable energy sources powering some of our cities. These technologies have changed the way we communicate, manage our well-being and engage with society. They have also shifted our expectations about what is possible, both now and in the not too distant future.

So what will the world look like in 20 to 30 years' time? To answer that question clearly, first we must explore how people view the role of technology and innovation in today's society. Our research found that for Europeans – from the UK, France, Italy, Germany, Spain and Norway – the biggest challenges our society faces in the decades to come are peace and conflict (54%), climate change (51%), air pollution (29%), and sustainable energy (28%). Each of these challenges speak to the need for stakeholders to focus on investing in and developing innovations that build a sustainable future, for the environment, for our cities and most importantly, for our people.

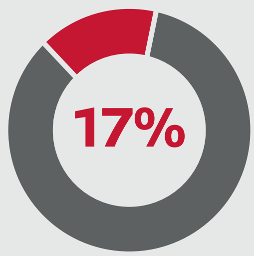


"We are working at the heart, the guts of the core technology and bringing insights and the kind of understanding that we have about human practices and human experience right into the fundamental design of the system."

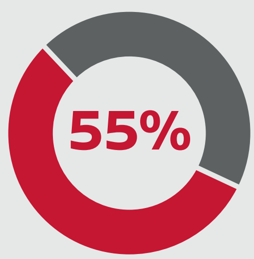
Melissa Cefkin
Principal Scientist and Design Anthropologist, Nissan Research Center, Silicon Valley

The innovations of the future that will address these challenges are expected to come from the ground up: more than half (55%) of Europeans expect start-ups and entrepreneurs to lead the way, signalling a belief that agility is more important than scale. The French (63%) and Spanish (60%) have the strongest belief in start-ups and entrepreneurs to lead the way. Interestingly, just 17 percent say they expect national governments to develop the best innovations of the future.

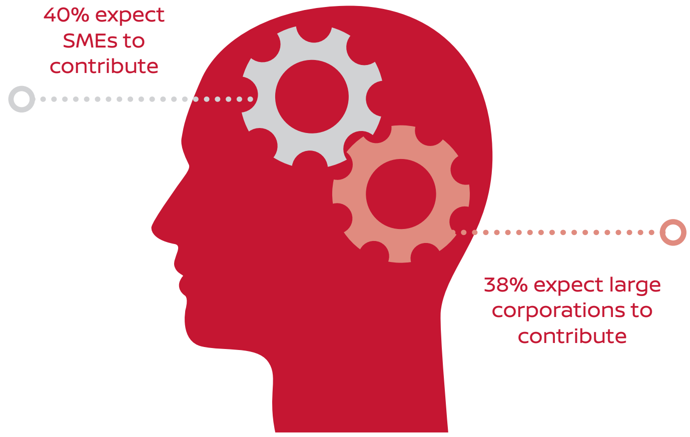
Europeans that believe Governments to lead the way



Europeans that believe Start-ups & Entrepreneurs to lead the way



Developing innovations

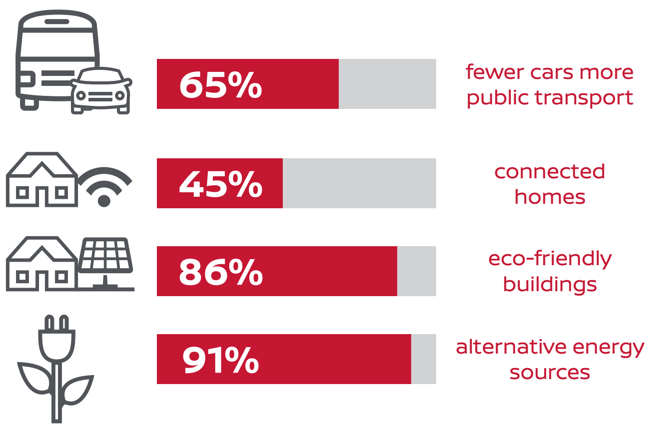


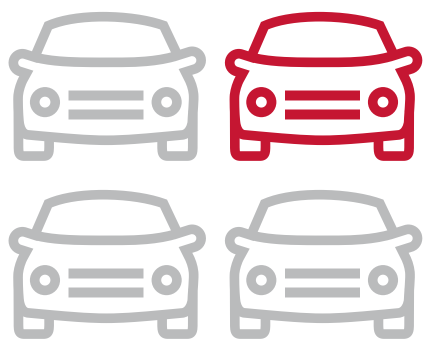
Still, small and medium sized business (40%) and large corporations (38%) are expected to play a role in developing these innovations to improve the way we live, particularly those involved in the medical (61%), technology (57%), or energy industries (50%). All of which points to a future that is more sustainable, responsible and progressive ...and the research shows that it's a future that Europeans are excited about.

They look forward to a world where there are more alternative energy sources developed (91%), recycled materials being used in more innovative ways (89%), more eco-friendly buildings built (86%), and fewer cars with more public transport (65%). In fact, nearly half (45%) are excited by connected homes, a concept that is fairly new to society but one that is on the rise both in terms of awareness and adoption.

But what about innovations in driving technology? While only one in four (26%) of Europeans said they expect the auto industry to deliver innovations to improve the way we live, over the last several years the industry has begun to develop and integrate technologies that make cars not only more energy efficient, but also more intelligent. These innovations signal a recognition of the role the industry has to play in working towards a smarter and more sustainable future.

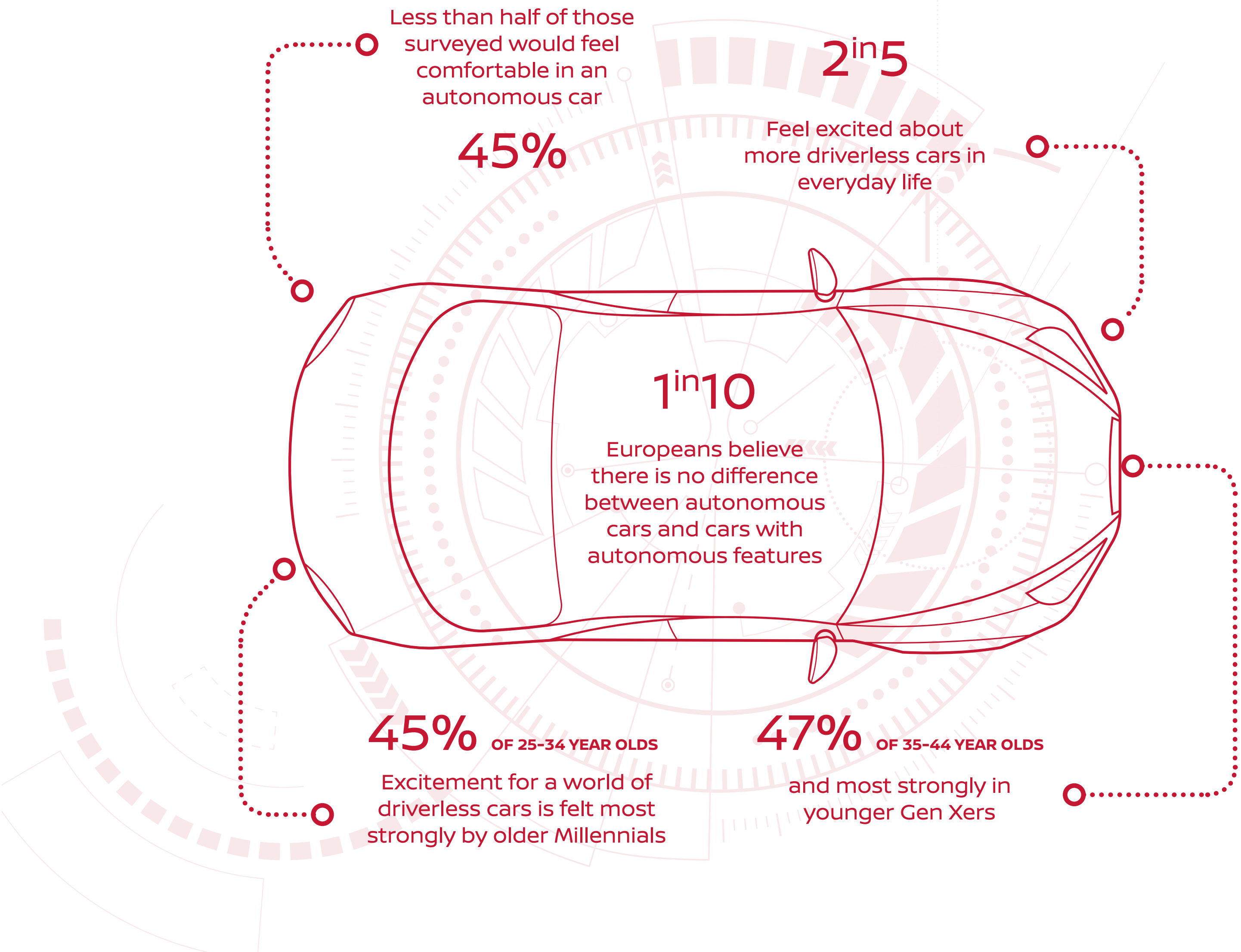
% of Europeans are excited by:





1 in 4

Expect the auto industry to deliver innovations to improve the way we live



For many stakeholders within the auto industry, that future is one in which driving is more autonomous. And while the industry can see this future on the horizon, for the everyday consumer the concept of autonomous driving, or driverless cars, is one they are still learning about and growing comfortable with. Less than half of those surveyed (45%) admitted they would feel comfortable riding in an autonomous car. And while comfort levels with autonomous cars is relatively low among respondents, nearly two in five (37%) admitted they are excited about the prospect of more driverless cars in everyday life. Excitement for a world of driverless cars is felt most strongly by older Millennials (45% of 25-34 year-olds) and younger Gen Xers (47% of 35-44 year-olds). Additionally, consumers living in Norway (46%) are most excited by a society with more driverless cars.

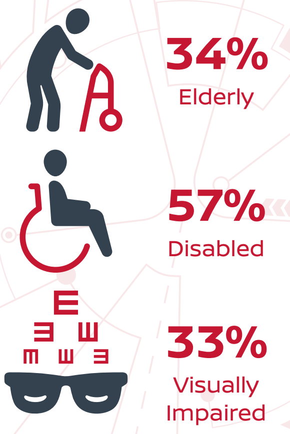
The results show that, as the auto industry continues to innovate, it is essential to communicate and ensure everyday consumers are fully educated about how these changes impact not only the cars they drive, but also how those cars integrate into an increasingly connected world. Indeed, our research points to a need for increased communication and education on the both the concept of autonomous cars as well as their innovations, from laying the groundwork of ideas to realising their potential.

A NEW DRIVING EXPERIENCE THAT BENEFITS SOCIETY

The biggest advantage Europeans expect to see with the introduction of autonomous cars is improved mobility for everyone (58%) – and they primarily see autonomous cars benefiting those who are disabled (57%), elderly (34%), and visually impaired (33%). Although access and mobility sits at the bottom of the list of challenges to be addressed in the next two to three decades, it is seen as the biggest societal advantage of autonomous cars, and can therefore be considered a key issue for autonomous car manufacturers to address.

Drivers also see autonomous cars as a way to get unsafe or poor drivers off the road (43%), and to ensure fewer drunken drivers are on the road (34%), thereby making the road a safer place for everyone, regardless of whether they're a driver, passenger, cyclist, or pedestrian.

Biggest advantage Europeans expect to see is improved mobility in:



Our research shows that there is still work to be done to close the gap between our exposure, understanding and acceptance of autonomous cars. And while for many the idea of accepting and using this technology seems distant, the quickest way to close that gap is through education and experience. While less than half of respondents reported they would feel comfortable riding in an autonomous car, they would feel more comfortable with it if they could try it first to see what it's like (47%). A sentiment that was felt strongly across markets, most notably in Germany (56%).

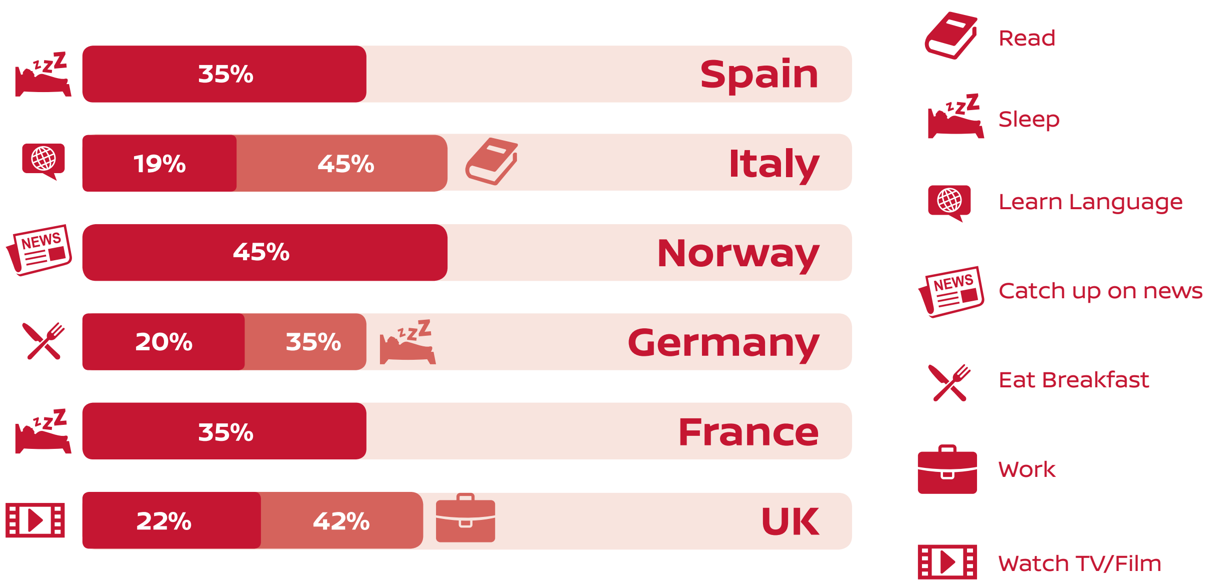
And while for many, expressing comfort with the technology must wait until they've had a chance to try it themselves, large numbers of respondents report they recognise the benefits to autonomous cars – both from a lifestyle and health perspective. Overall, about half of Europeans agree that autonomous cars could improve their lifestyle by reducing stress (48%). After all, one in five (21%) admit they feel stressed driving others somewhere and a similar percentage (18%) feel stressed driving themselves somewhere.

Beyond the potential lifestyle benefits, Europeans identify lower stress levels (56%) as the main health benefit of autonomous cars, along with fewer car accidents (56%). Recognition of both these benefits points towards the fact that many Europeans recognise that there are health benefits to autonomous cars, even without ever having experienced them. Once they experience autonomous cars for themselves, they will likely have an even better understanding of the health benefits that accompany a world in which autonomous cars exist.

In addition to lowering stress, Europeans believe that future autonomous cars could give them the ability to do something other than drive (50%), and could give them the health benefit of having more free time (30%). With the extra time that riding in an autonomous car would give them, many people would choose to be productive, spending the extra time in the car but not driving by reading books (37%), catching up on the news (37%), or getting work done (30%). That said, one in three say they'd spend that time sleeping (33%).

Beyond activities, some drivers even see autonomous cars as a way to keep more money in their own pocket (28%), as they may not need car insurance, make car payments, or pay parking fees. A similar percentage see it as a way to reduce traffic (25%), also giving them the flexibility not to own a car (26%).

The freedom they love when they hit the road won't disappear with the advent of autonomous cars. If anything, it will give them even more freedom – to spend their time in the best way possible, to spend their money the way that they like, and to go wherever they desire without the stress that often accompanies driving.

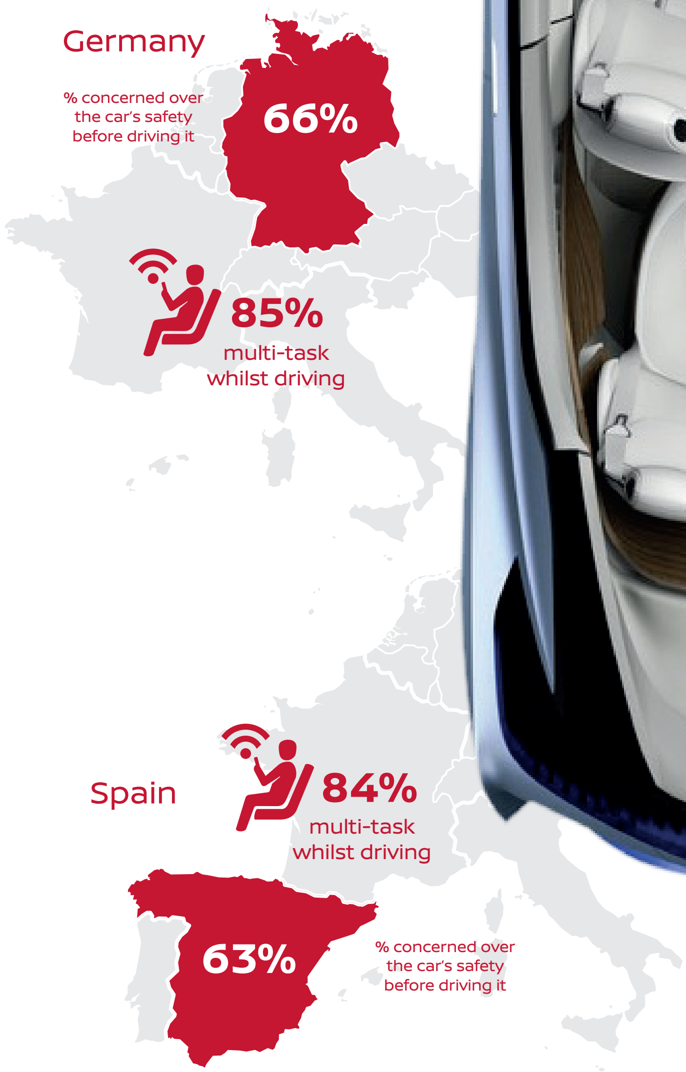


TECHNOLOGY'S ROLE IN ADDRESSING CAR SAFETY

Car safety is top of mind for Europeans, and sits first in a list of concerns they have when they drive a car that's unfamiliar to them. Car safety (57%) is closely followed by two other safety-related concerns: locating the lights (52%) and making sure they can see well out the rear window (51%).

Despite this concern for the safety of the car, four out of five drivers (81%) admit that they've performed multitasking activities while driving, with most admitting that they have changed the radio station (68%), eaten a meal or snack (42%), or drunk a hot beverage (25%) while driving. Among the most dangerous behaviours? Texting, which one in five (18%) admit to have done while driving.

Autonomous cars could limit the amount of unsafe multitasking performed while driving, with half of Europeans (50%) believing the main lifestyle benefit to autonomous cars is the ability to do something other than drive while in the car – allowing them to do the tasks that could otherwise cause accidents. Although the ability to do other things while driving tops the list of lifestyle benefits of autonomous cars, the safety of such cars is a significant concern for Europeans.



Although Germany (66%) and Spain (63%) are the markets most concerned with how safe the car is before they drive it, they are also the markets most likely to say they've multi-tasked while driving – 85% in Germany, and 84% in Spain.

In fact, about half (48%) believe that the main disadvantage of autonomous cars would be the possibility of the technology not working, which, like multitasking, may lead to an accident. And when it comes to lifestyle drawbacks of autonomous cars, a majority of Europeans identify the heavy reliance on technology as the biggest drawback (65%).

"Autonomously-equipped vehicles will improve the safety and well-being of drivers, with fewer collisions and reduced traffic congestion. The UK economy can also benefit, by playing a pivotal role in a global industry estimated to be worth £900 billion by 2025."

Paul Willcox
Chairman, Nissan Europe

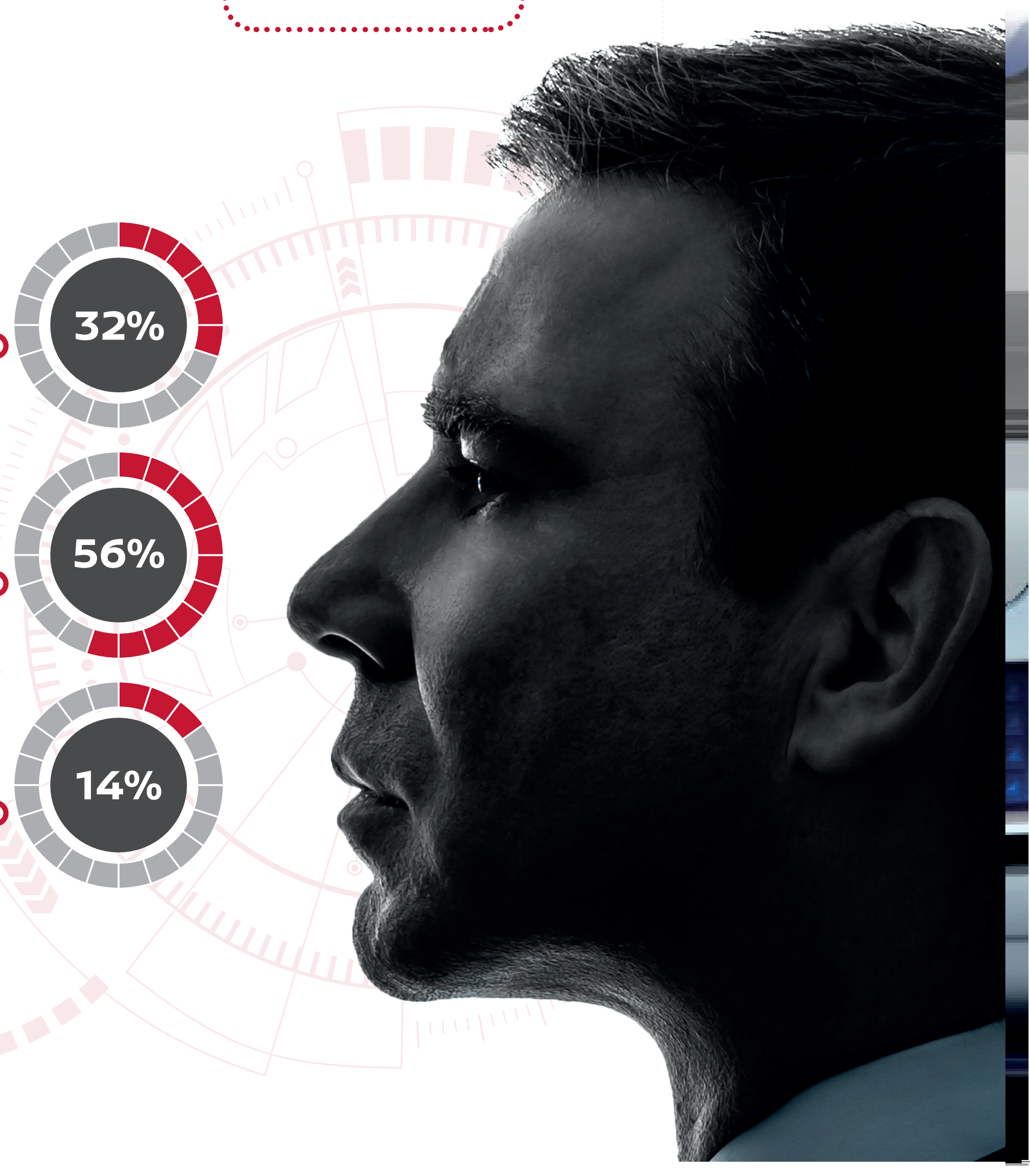
The technology industry will play an important role in the development and adoption of autonomous cars. The tech industry will not only be responsible for working with car manufacturers to ensure that technology addresses every aspect of an autonomous car's safety, but it will also need to interact with drivers to allay their concerns about the safety of such cars from a technological perspective. Indeed, among those who are uncomfortable with the idea of riding in an autonomous car, one in three (32%) say that more advanced technology would help them feel more comfortable with the idea, and among all Europeans the same percentage (32%) worry about the car's computer being hacked.

In 2016, cybersecurity is a very real concern for many consumers, whether they drive or not. Protecting privacy is very important to consumers, and the fact that a car essentially runs on technology worries them. In Germany, concern around cybersecurity is highest (42%), followed by France (35%) and Norway (34%). Least concerned? Spain (25%), Italy (28%), and the UK (30%). Transparency around how their cybersecurity is protected will be important for potential users of autonomous cars to understand.

The percentage of Europeans that worry about the car's computer being hacked

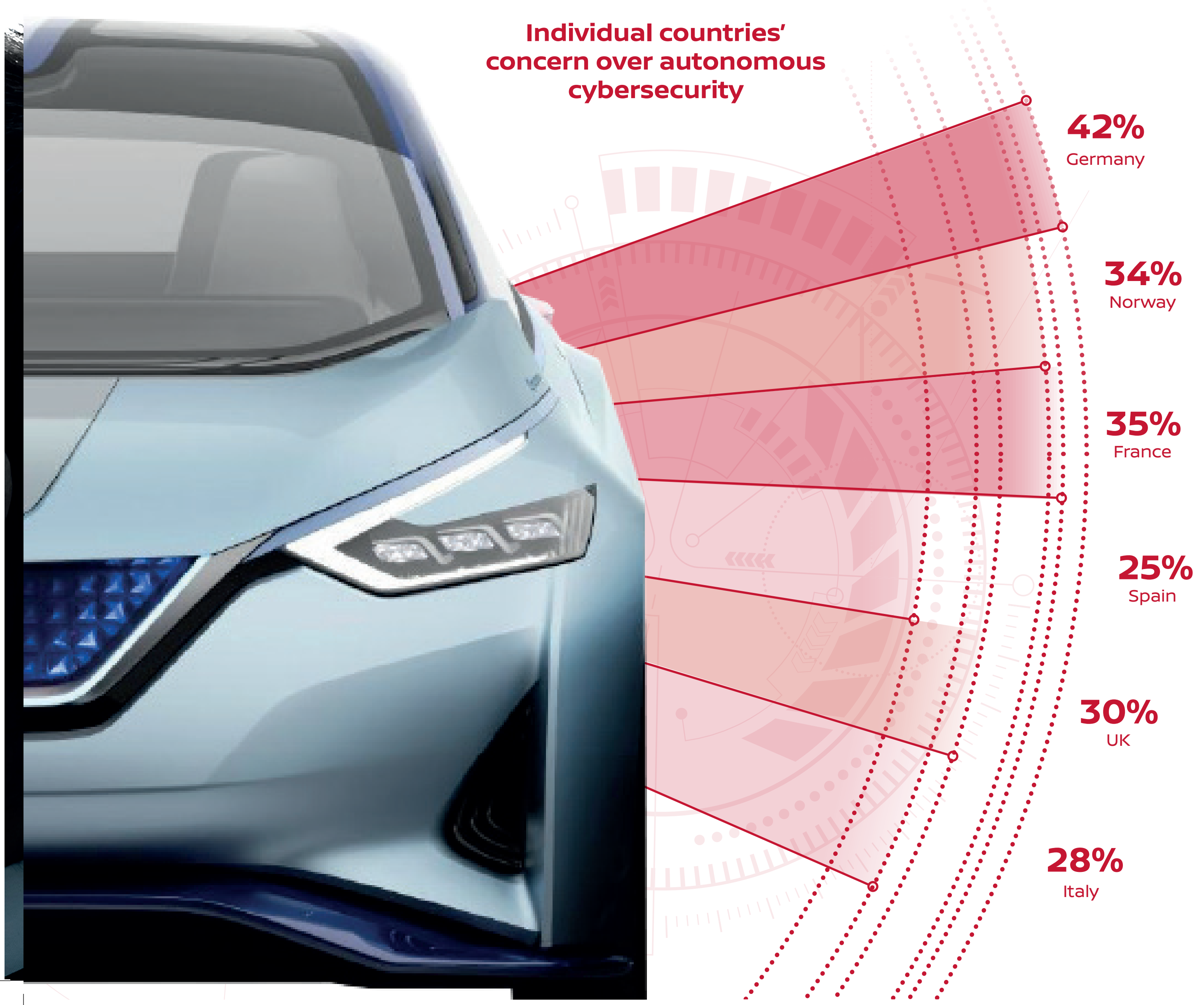
The percentage of Europeans that ranked fewer accidents and lower stress levels equally as the top health benefits of autonomous cars

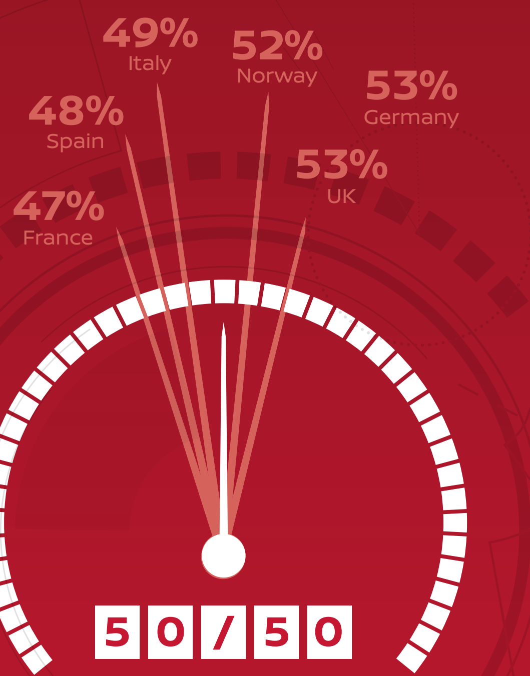
The percentage of Europeans that are concerned about human error causing an accident in an autonomous car



Despite safety concerns around autonomous cars, Europeans certainly also see safety benefits to them. They can most clearly identify the benefits to autonomous cars when it comes to the possibility for these cars to help reduce the number of accidents caused by human error (52%). In terms of concerns about autonomous cars, only 14% worry about human error causing an accident – which shows they understand that many accidents are caused by human error, and that autonomous cars could help to reduce this cause of accidents. Beyond improved safety, Europeans also see how autonomous cars can improve health, citing fewer accidents as a top health benefit (56%).

While there is a large role for the technology industry to play in creating the safest possible autonomous car, Europeans' biggest safety concern of autonomous cars actually revolves around control – or lack thereof – in such a vehicle.





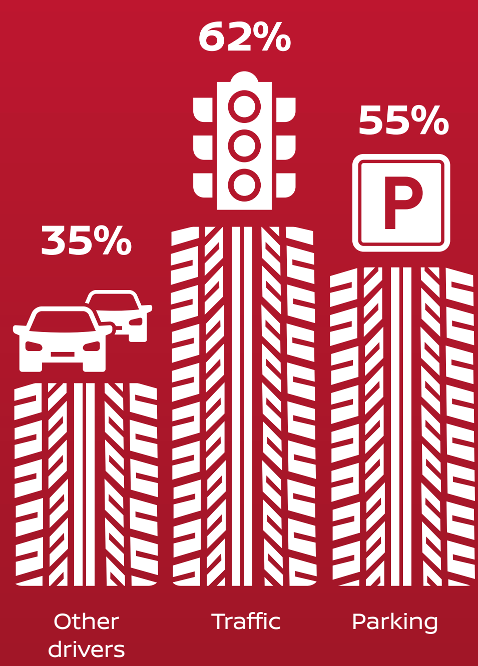
Europeans 50/50 on concern over losing control to autonomous vehicles

Staying In Control

Part of the appeal of driving is the sense of control it gives people – they are in complete control of where they go, when they want to go, and which route they will take to get there. While many Europeans say their favourite thing about driving is being in control (46%), even more say that their biggest safety concern about autonomous cars is not having control of the vehicle themselves (50%). It seems there are still concerns around relinquishing this control. Although 45% of Europeans say they are comfortable with the idea of riding in an autonomous car, for the remaining 55%, it will take time to overcome the idea of letting go of this control and driving in a new way that's safer for everyone.

Some of Europeans' least favourite things about driving are things over which they have little to no control – sitting in traffic (62%), finding parking (55%), and other drivers (35%). One in four Europeans (25%) believe that autonomous cars will reduce traffic overall.

Europeans' least favourite things about driving



For Europeans, the best things about driving includes the freedom to go wherever they want (73%) and having a means of transportation at any time (60%), followed by being in control (46%). In the forthcoming autonomous revolution, people will be just as mobile as ever – if not more so – as autonomous cars democratise transportation and allow those who never learned to drive, don't hold a licence, or are unable to drive, to get where they want to go in a convenient manner. And, as previously stated, a huge benefit that many Europeans see with autonomous cars is a reduction in accidents, especially those caused by human error.

"The key to getting people comfortable with the idea of autonomous driving is to make drivers feel at one with their cars, yet still in control. You're building this intelligent entity that has to cooperate, coordinate, and collaborate with humans. That's why we won't yank away the driver's steering wheel, and why we're adding features bit by bit."

Maarten Sierhuis
Director, Nissan Research Center
Silicon Valley

26%
Europeans feel stressed when a passenger

18%
Europeans feel stressed when driving

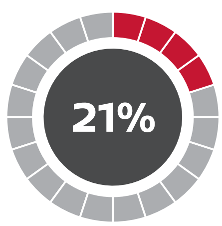
However, one of the biggest hesitations that people have is around who – or what – would be at fault in the event of an accident with an autonomous car. Drivers want assurance that they won't be to blame in the event of an accident, but are split on who or what would be.

Among those who feel uncomfortable with the thought of riding in autonomous car, one in three (33%) admit that they would feel better if there was assurance they wouldn't be held accountable. Across all markets at the total level, many believe that the car manufacturer (29%) or the software company (25%) would most be at fault in the event of an autonomous car hitting a person on the road. One in five Europeans (21%) believe that they would be at fault if such an event were to occur.

It will be important for autonomous car manufacturers to speak directly to consumers and address the improvement in car and road safety that autonomous cars will have, while simultaneously soothing drivers' fears of giving up control to a machine. While it is an unfamiliar idea, it is not dissimilar to when they are a passenger in a car or flying in a plane – a situation in which one in four Europeans feels stressed (26% and 24%, respectively). Indeed, only one in five (18%) admit to feeling stressed when they are driving themselves somewhere – highlighting that while driving and riding in a car can be stressful, far fewer feel stressed when they're in control.

The percentage of Europeans that believe car manufacturers would be most at fault in the event of an autonomous car hitting a person

One in five Europeans believe that they would be at fault in the event of an autonomous car hitting a person



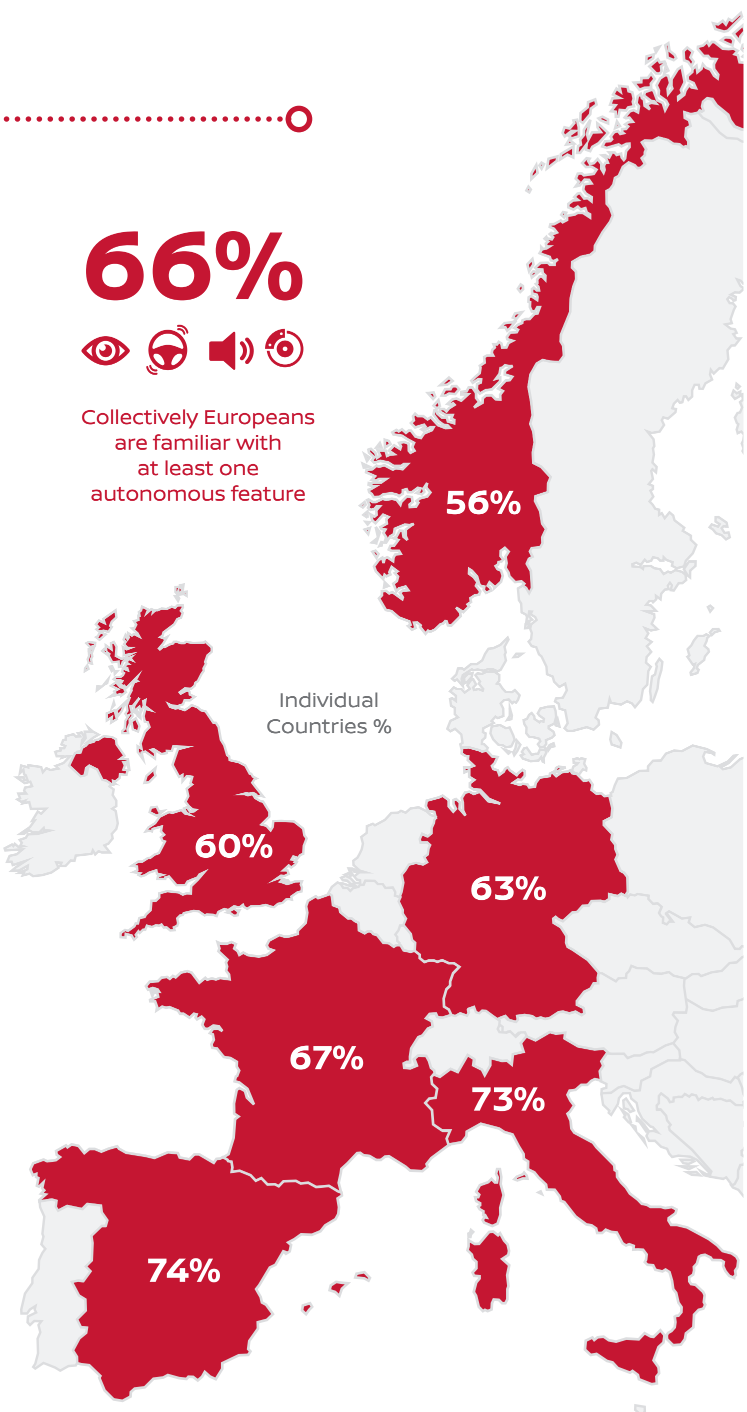
The percentage of Europeans that believe software companies would be most at fault in the event of an autonomous car hitting a person

But autonomous cars won't be fully autonomous for some time – drivers will still hold some physical control of the vehicle, and will primarily be assisted by the technology rather than controlled by the technology. Although only one in three Europeans say they know the difference between a self-driving car and a car with autonomous features, they are more familiar with autonomous driving features than they realise.

Overall, 66% are familiar with at least one autonomous feature, and tend to believe that they are designed to assist rather than replace the driver, and that they can make driving safer.

In terms of specific autonomous features, half are familiar with parking assist (50%), and realise that it is designed to assist rather than replace the driver (42%). One in three are familiar with intelligent emergency braking (35%), and believe it makes driving safer (52%).

Safer driving conditions will have benefits for all – whether in the driver's seat, passenger's seat, or on the road as a cyclist or pedestrian. Safer driving conditions also mean fewer accidents, a top concern for Europeans when it comes to driving. Autonomous cars will help decrease accidents, and have many other societal benefits as well.



Conclusion

Overall, this study shows that consumers are beginning to understand the benefits of autonomous cars, from reducing the number of accidents caused by human error to lowering stress levels, saving time and improving access to mobility for everyone. As with any new technology however, there are still some concerns and these are mainly related to the idea of relinquishing control to technology, as well as who would be liable in the event of an accident – which is already a complicated business for drivers today.

There is of course still more work to be done to lay the groundwork for autonomous technology – by regulators, carmakers and the technology companies we work with. Clearly, car makers need to continue to communicate and educate in order to ensure that consumers truly trust this technology and the companies that provide it.

As with most innovations, autonomous drive technology will improve people's lives, and create a safer, more enjoyable driving experience. But to achieve that, the technology itself needs to be accepted, understood and embraced.

The Nissan Social Index
Consumer Attitudes to Autonomous Drive

Nissan Europe commissioned a survey in October 2016 examining people's attitudes towards autonomous drive technologies and the future of mobility. In total, approximately 6,000 people were polled across six European countries – UK, France, Germany, Spain, Italy and Norway.