



Driverless Futures

Design for acceptance and adoption
in urban environments



Fig 1. Inside front and back cover: This image shows a future London where driverless vehicles have changed the city and how we live in it: drones criss-cross the sky; delivery pods clamber up the sides of tall buildings; robots queue for jobs at the robot job centre and single pods transporting sleeping passengers in herds from home to office and back again

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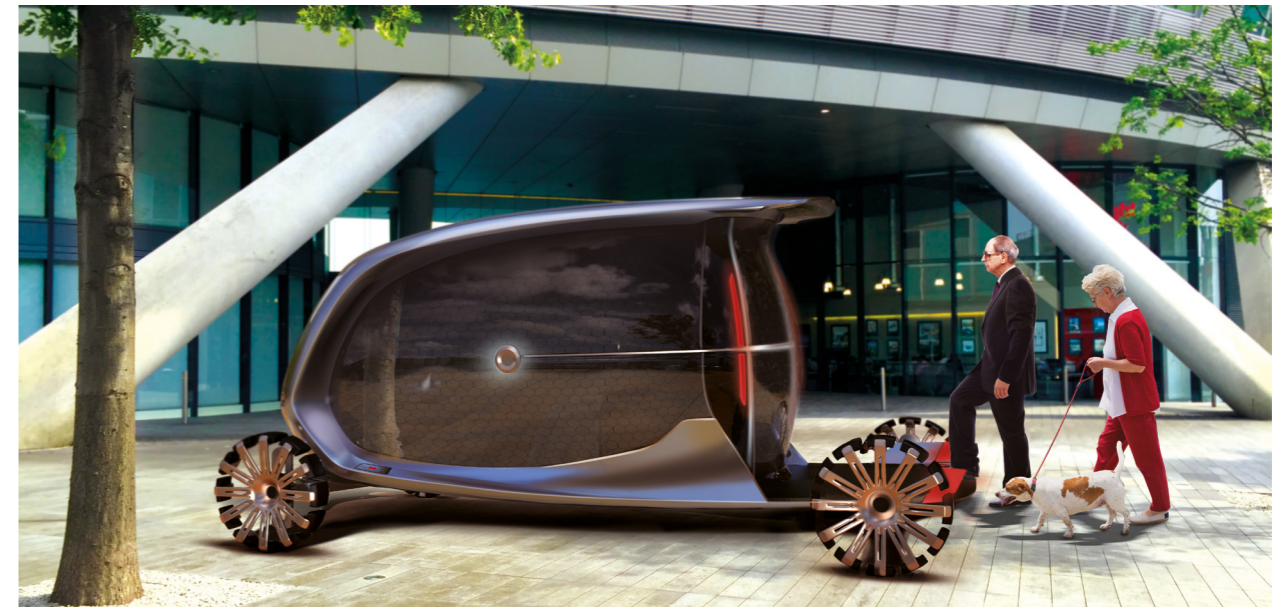
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The GATEway project has been joint-funded by government and industry. It has received £5.5 million in funding from the Department for Transport (DfT) and the Department for Business, Innovation & Skills (BIS) through Innovate UK and is supported by the Centre for Connected and Autonomous Vehicles (CCAV), which is the UK government policy unit set up to drive the governments activity on connected and autonomous vehicles. This funding is supported by an additional £2.5 million from the commercial organisations within the GATEway consortium.

ISBN: 978-1-910642-32-0

Fig 2: Future vehicles should be accessible for all. Integrated assistance helps everyone to get around more easily without highlighting a person's disability



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Fig 3: The GATEway driverless vehicle exhibit at the New Old exhibition, which took place from 12 January-19 February 2017 at the Design Museum in London. New Old explored the potential for design and designers to enhance the experience of our later lives

Foreword

From folk tales of flying carpets to appearances in science-fiction movies, autonomous vehicles have gripped our imagination around the world. Now, mobility is set for the greatest change since the invention of the internal combustion engine. People see the rise of driverless cars in a variety of ways, from the excitement of new possibilities and eagerness to try them to fears over lack of control and outright scepticism.

Driverless vehicles could bring real benefits for older people, through maintaining mobility and accessing community services. Mobility is a key indicator of quality of life, with ownership of a driving licence still important to many people. Losing their licence because of health or sensory decline can significantly affect people's self-worth.

Easy-to-use driverless cars could allow everyone to get around, regardless of age or ability. A visual impairment or significant loss of dexterity would not be a barrier to using a vehicle, creating radical new possibilities for more inclusive mobility.

The last kilometre of any journey can pose significant issues for older people who find walking long distances challenging. Existing modes of public transport such as trains, buses and trams typically get people fairly close to their home, leaving taxis or private cars as the only true forms of door-to-door transport.

A driverless car could become part of a truly door-to-door transport network. This is particularly valuable in suburban and rural contexts where public transport services

tend to be less regular and further from people's homes.

Although driverless cars can feel futuristic, vehicle autonomy has been around in different forms for a while. Late nineteenth-century and early twentieth-century horse-drawn milk floats in the UK often relied on the horse to stop in front of each dwelling to allow the milkman to make deliveries. In countries where horses and carts are still prevalent, stories abound of the animal finding its way home if the driver was incapacitated.

Auto-helm systems have been used on boats since the nineteenth century, with electronic systems now optimizing many journeys without human input. Many of us step on a plane with little realization that an autopilot system will do most of the flying, especially the complicated bits such as landing. In fact, international aviation standards mandate that planes with 20 or more seats need to have some form of autopilot and modern jetliners often self-correct more quickly and accurately than a human.

Autonomous trains are perhaps the closest contact that most of us have had with a driverless experience. London's Victoria line was the first to have automatic train operation in 1967. Various levels of automation have appeared since, from those supported by a person to fully automated systems such as Gatwick Airport's People Mover that launched in 1983. The positive public perception of trains may go some way to help reduce anxieties and fears around driverless cars.

On the cusp of change

Today, we are on the cusp of a significant change as autonomous vehicles approach everyday travel. The development of autonomy, electrification and connectivity are driving change – with potentially huge benefits in terms of safety, traffic congestion and convenience, which will smooth adoption.

The motor car, the defining machine of the twentieth century and the technological achievement that facilitated private transport for the masses, is the basis for the driverless car of the twenty-first century. The birth of modern car design was dominated first by engineering and manufacture, then by branding. The car industry now has to face up to a changing cultural, social and environmental landscape of increasing autonomy.

The first truly autonomous, full-size cars ran in the 1950s and 1960s in the US and the UK. Cables and detector circuits embedded in the road guided the vehicles, which were converted stock cars.

The 1970s and 1980s saw cars detach control from the road and read cues in the environment using cameras. By the 1990s, governments started funding new technologies with the potential to reduce traffic congestion and accidents. A number of vehicle manufacturers developed technologies such as night vision, active cruise control and lane departure warning, often in collaboration with academia.

In 2014, Google revealed its first in-house prototype, a small two-seater vehicle with friendly product design features rather than

the sweeping curves normally associated with vehicle design. With no pedals or steering wheel, this was a purpose-built driverless vehicle – not a converted car. The same year saw another radical shift as electric-car company Tesla equipped its Model S with 12 ultrasonic sensors and a forward-facing camera to support autonomous driving.

Autonomous vehicles really moved into the public eye in 2015 with high-profile journeys such as a United States coast-to-coast record for a driverless car and several brands entering the arena. Volvo boldly stated that it would accept liability for any of its driverless vehicles involved in accidents and BMW launched an autonomous parking feature for its luxury models. Nissan prototyped an interior with ‘driver’ and ‘driven’ modes and General Motors and Toyota tested driverless prototypes. Tesla even updated its vehicle software to enable an ‘autopilot’ function, and non-car companies such as Chinese social network Baidu and mobility disrupter Uber also got in on the act and tested vehicles on the road.

A people-centred approach

At the Royal College of Art, we’ve been taking a human-centred approach to the design of autonomous vehicles, systems and services. As designers, we’re working with people of all ages in teams including scientists, technologists, social scientists and others to find new solutions in this dynamic sector. Open design and social media can enable members of the public to test solutions so that the design process becomes more democratic, moving beyond traditional vehicle design.

We have looked at social and cultural expectations, including fears, around driverless cars. It is important to reassure people that a car will make good choices on city streets and to prevent pedestrians from halting a vehicle by simply standing in front of it. Imagine the new possibilities as people and goods are driven around. Could hotels operate vehicles as mobile rooms, silently whisking guests across the country overnight? Or could a car be a mobile nanny, entertaining children and picking them up from school?

The driverless car is pulling up fast. It could bring enormous benefits to older people at a time of increased longevity and demands on healthcare and fewer people working to support those who are retired. Could it help mediate between the generations, taking grandparents to meet grandchildren without needing to negotiate a lift from parents? Could autonomous ambulances support patient transport and discharge, and driverless community vehicles bring much-needed services to a person’s doorstep?

Whatever the outcomes, the driverless car has real potential to improve the mobility, access and visibility of many people including young and old, able and disabled and those with limited resources. The intelligence is already there – we must make sure that inclusivity follows.



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Executive Summary

'How does design help to increase the acceptance and adoption of driverless vehicles in urban environments?'

GATEway (Greenwich Automated Transport Environment) is an £8m research project that aims to understand and overcome the technical, legal and social challenges of implementing automated vehicles in an urban environment.

The GATEway consortium includes leading companies and academic institutions and is supported by Innovate UK and the Centre for Connected and Autonomous Vehicles.

The Royal College of Art leads the public engagement work stream and our research question is, 'How does design help to increase the acceptance and adoption of driverless vehicles in urban environments?'

The RCA's team includes designers and researchers from The Helen Hamlyn Centre for Design and the Intelligent Mobility Design Centre.

We have been exploring the public's attitude towards driverless technology in an effort to understand how their preconceptions of autonomous vehicles might be taken into account in the design of future vehicles, services and infrastructure; with a focus on the views of Londoners and London's urban environment.

Between 2016 and 2017 we carried out desk research, interviewed experts, ran a series of pre-trial workshops with members of the public; held an interactive exhibition on driverless futures at the London Transport Museum; and carried out a number of group

activities inside an autonomous shuttle on the Greenwich peninsula, where we prototyped future commutes, shopping trips and leisure journeys.

We used this research to understand the role of design in increasing the acceptance and adoption of driverless vehicles in urban environments; what are people's hopes and fears, and their needs and aspirations, and how might they shape a driverless future?

This publication sets out to answer these questions by sharing stories from future Londoners, the services that they will use, the vehicles that will support them on their journeys and the impact that these will have on our city's infrastructure and environment. We have set these stories in 2035 , when autonomous technology will be ubiquitously available and we describe a preferable future that meets people's needs and aspirations while taking into account the environmental, social and economic challenges that cities will face.

We share design patterns that communities and organisations should consider when developing future autonomous mobility services, vehicles and infrastructure.

We also set out potential road maps towards this driverless future, indicating who might benefit most from autonomy; which services will be most acceptable; how the environment and infrastructure of the city might adapt to provide benefits for every Londoner; while creating a pathway for universal autonomous mobility that provides citizens with social, environmental and economic benefits including safer streets, more inclusive environments, and cleaner and calmer

cityscapes where people, rather than vehicles, are put at the figurative centre of our public and civic space.

Finally, we describe the research methods that we used to reach these conclusions and further research opportunities that arise from this work.



Fig 4: The GATEway driverless shuttle, nicknamed Harry, which was used by RCA researchers to investigate people's attitudes and behaviours in an autonomous vehicles during research in Spring 2017

Introduction

Audience

This publication is aimed at a wide range of people and stakeholders who might be interested in the future of driverless vehicles to show how design can be used to increase their acceptance and adoption in urban environments.

We hope that it will be of value to all sectors directly involved in the development of driverless vehicles; to government planning departments, policy-makers and standards organisations; to businesses and organisations developing mobility services and infrastructure; and to disempowered groups including the elderly, the infirm and those with limited resources.

Aims and objectives for the publication

Our aim is to share new knowledge about driverless vehicles and systems that incorporate autonomous technology, as well as insights into the attitudes and behaviours of city dwellers and how these might influence the acceptance and adoption of driverless services.

Our objectives include:

Sharing the hopes and fears of the general public when thinking about driverless systems in an urban setting.

Setting out a series of design challenges and opportunities based on these hopes and fears.

Describing the potential lives of future Londoners with a focus on how they make use of driverless vehicles and services in their lives.

Illustrating designs for a range of future driverless vehicles, showing how these meet the needs of city dwellers and how they may affect future guidelines and vehicle standards.

Indicating how the urban environment and infrastructure might adapt to take into account the different ownership and usage patterns of driverless vehicles as well as taking into account some of London's social, environmental and economic challenges.

Proposing a set of design patterns that can be used to create culturally relevant solutions in different urban environments.

Setting out road maps that show how vehicles, services, city environments and infrastructure might be developed over time to support the acceptance and adoption of autonomous vehicles; including helping people to understand and be part of this process of transformation rather than simply being recipients of the technology.

Summarising our research methods and the techniques that we have used to develop these future scenarios in the hope that they will be of value to other organisations as they go about creating future products and services that are both inclusive and socially, environmentally and economically beneficial.



Fig 5: Members of the public and RCA researchers discuss their hopes and fears for a driverless future during workshops in Summer 2016

1.0

People, their Needs and Aspirations

This chapter summarises the outcomes from our research. We explain who we met during our research and the characters that we are using to illustrate a preferable future; the hopes and fears of the public today; the design opportunities and challenges that come from these concerns and aspirations; and the range of activities that people imagined doing in future driverless vehicles, including both the mundane and the surreal.



The methods used by the Royal College of Art researchers on GATEway comprised: workshops including interviews and co-design activities with a range of users and potential users; interviews with users of test vehicles; exhibitions involving engagement activities with the public and experts; and design, including aspects of experience design, service design and urban design as well as designing vehicles and future mobility platforms. As we note often in this publication, designing within GATEway was about creating stimuli and provocations, as a means of understanding users' reactions and alternative ideas, rather than designing "solutions". Design here is effectively a research method. To explain this, we briefly set out the meaning of design research, which begins with the first, conceptual framing of a project, unlike design which is often confined to deciding what things should look like after many fundamental decisions have been taken.

The Royal College of Art has pioneered design research over more than half a century. In the early 1960s, the College's professor Bruce Archer helped to invent the discipline. He originally aimed to turn design into a kind of science, but from that idea emerged something quite different – the idea that design might be a third way of understanding and making the world, one as distinct from the text-based humanities as from the sciences (Archer 1968, 1979; Boyd Davis & Gristwood 2018). This idea of design as a special way of approaching questions and problems has more recently been popularised as design thinking – unfortunately often ill-defined, and

sometimes presented as the answer to every problem (Iskander 2018). In this introduction, we highlight specific aspects of design research that have enabled us to focus on the human being who can be considered the focus of any designing (with important caveats discussed below).

Twenty years ago, cultural probes (Gaver, Dunne & Pacenti 1999) were another RCA landmark: they had several features that are still important for a project like GATEway. They were not intended to establish general principles about the behaviour of a large population, but instead to discover the distinctive attitudes and behaviours of individuals and small groups. The probes were two-way: capturing information, they also provoked and stimulated discussion among the participants, leading to new insights unforeseen by either the participants or the researchers. This focus on depth and specificity, rather than generalisation, has been carried through into the GATEway project.

At the same period, the RCA Helen Hamlyn Centre for Design was founded, building on the DesignAge research group created in 1991. Its philosophy has throughout been one of inclusive design – design that serves the needs of many in society, including those often neglected by mainstream design. Originally focused on those with different physical capabilities, it increasingly also deals with those who are not neurotypical (e.g. Gaudion et al. 2014). A key method has often been design ethnography. In traditional ethnography, it is generally assumed that the ethnographer is not attempting to alter the community that is being studied. Design ethnography, by contrast, is a form of action research (Lewin 1946; Swann 2002), that generally has exactly

that aim: to alter things for the better – in the words of Simon's *The Sciences of the Artificial*, "the transformation of existing conditions into preferred ones" (Simon 1969:111). Another key feature of the design-ethnographic approach is that it locates designing far from its traditional position towards the close of the innovation cycle – and instead moves it to the very earliest stages of problem definition and discovery. This determines not only what is to be designed, but sometimes also what should not be designed (Sanders and Stappers 2014:7). As Sless (2002:8) has put it, "this type of boundary shifting in design is quite common. But it is not simply a technical issue. Such shifts involve changes in values, implying changes in responsibility, control, ethics, and economics."

Involving users and potential users of products and services at the earliest stages alters the relationships between users (and potential users) and researchers. The idea of designing for people, can be rethought as designing with people, even designing by people for their own needs (Fulton-Suri 2007). Co-operative design aims to involve everyone in decisions and processes that the designer facilitates (Ehn and Kyng 1987; Kraft and Bansler 1994), while truly participatory design involves people as authors, instigators and designers of their own solutions (Sanders and Dandavate, 1999). This is a powerful tool for engaging non-designers – who, after all are the vast majority of users – within the design process. In Cross's words "everyone can – and does – design" (Cross 2011:3). While the designer is an expert in design, the user is often the expert in their own needs.

Human-centredness focuses on actual users and potential users (Liedtka, Salzman and Azer 2017; Newton and Riggs, 2016; Roberts, Fisher and Trowbridge 2015). But terms like "user" or "consumer" can obscure deeper connections with an individual, objectifying users and seeing them as test subjects rather than as complete human beings with needs, aspirations, ambitions, anxieties and fears (Gheerawo 2018). In a sequence of eight workshops within the GATEway project, people shared over 700 "hopes" and a similar number of "fears". With only 6% saying that they had a good knowledge of driverless cars, this allowed us to "take the temperature" of potential use. We found that those currently excluded from driving, including older people and those with additional needs, might be the most attracted to the benefits of autonomous vehicles. The findings from these initial workshops presented both utopian and dystopian futures; design thinking was central in eliciting, mapping and understanding their responses. It enabled workshop participants to express their hopes and fears in a way that was descriptive, imaginative and even unexpected. It further enabled the translation of ideas into opportunities for innovation that challenged the purely functional or technical focus that typically surrounds driverless vehicles, and created better social experiences and outcomes that are more relevant to the potential users.

A key element of design research is the production of prototypes, often low-fidelity try-outs of emergent ideas. It might seem that the obvious way to develop new solutions is to first fully understand the problem, before embarking on any kind of invention, but it has been shown many times that making ideas external – creating visual, tactile objects that capture ideas in material form – is itself a powerful way to test ideas (Boyd Davis & Vane 2019). It can enable people to go beyond the limits of their imagination and overcome innovation barriers (Buchanan, 1998). As already noted, even when our professional mobility designers created images and models, that does not mean they were proposing “solutions”: often the artefacts made were provocations, stimuli to discussion, engagement and argument. Phrases like “autonomous vehicle” or “last-mile interchange” or “mobility as a service” invite the very reasonable response, “Yes, but what do you actually mean?!”; design enables us to share some of the realities of what these things may look like, feel like, be sense-able as, in the real world. Then we can say, “No, that is not what I meant at all!”, or “Have you thought of making it like this?”

Finally, it is important to note some key limitations of user-centred design, limitations that we have taken into account in GATEway. Stakeholders are easily conceptualised if they are identifiable individuals or groups and are present now. But what about entities less easy to pin down, such as society at large, ecosystems, non-human animals, and indeed our future selves? Human-centred design offers a model of the human as a discrete, individual subject, often prey to powerful commercial and social forces (Forlano 2017): it is essential to recognise other models of who

we are designing for, summed up as society and the world. The first, society, recognises the needs, and the power, of social groups, organisations and networks. The second, the world, corrects the anthropocentric assumption, recognising that current forms of human life are unsustainable and that humans are dependent on the Earth’s wellbeing and its limited resources (Acosta and Romeva 2010). To illustrate: a claim of companies like Uber and Lyft is that ride-hailing and ride-sharing reduce traffic volumes and congestion, yet the opposite has been found in reality (Erhardt et al. 2019). At no point in our research have we assumed that autonomous vehicles, industrial growth, increased mobility, or even increased personal freedom, are our goals.

1.2

Who are we serving?

We met a range of people during one-to-one conversations and design sessions, at workshops, exhibitions and in-vehicle trials. They included drivers and non-drivers, parents and children, people with additional needs and those who classed themselves as technology enthusiasts or professional stakeholders as well as design students and postgraduates.

They do not represent every demographic of London but they helped us to build a more detailed picture from a diverse group of voices. While some were young, able-bodied and mobile, others were retired, had a range of disabilities and were cautious about new technology.

For the purposes of this publication we have chosen four groups of people who represent a significant proportion of typical Londoners. These include a family, an older couple, a young person with additional needs and a youngster with limited income.



Fig 6: RCA researchers worked with a range of people during our research. (Clockwise from Top Left) Pre-trial creative workshops, In-vehicle research with able and disabled people, and workshops during the Driverless Futures Exhibition at the London Transport Museum

1.3

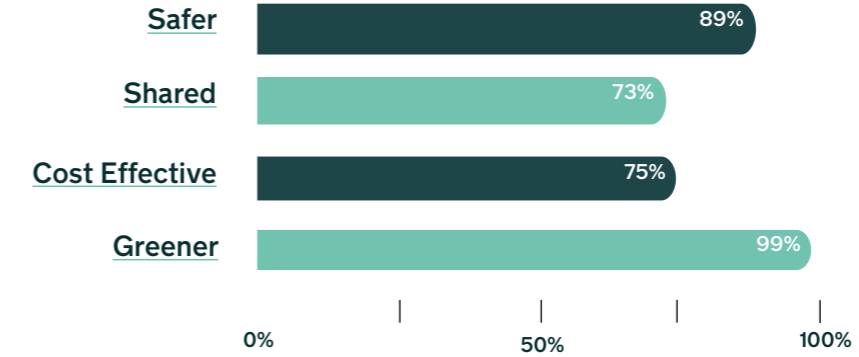
Knowledge and attitudes

TRL recruited people for the workshops based on a range of criteria and aimed to avoid positive bias by ensuring that we limited the number of ‘technology enthusiasts’ and had a wide range of participants including drivers, non drivers, people with additional needs, technology enthusiasts and professional stakeholders. Despite this, most were positive about the technology with only a quarter unsure and 1% concerned. The majority felt that these vehicles would be safer, greener and more cost effective, with less than a third thinking that they would be owned rather than shared.

Hidden within these attitudes are fundamental hopes for a safer, more inclusive, cleaner and calmer city where streets and places are designed for people rather than for vehicles and the supporting infrastructure that currently dominates their design. Many participants thought that driverless vehicles were the future of transport in the city, and the network of vehicles and sensors would create an exciting, efficient and potentially revolutionary transformation in how cities develop both spatially and economically.

As for the activities that they imagined doing in them, they mainly reflected current behaviours on public transport such as reading, watching media, chatting with friends or having a nap. Some expressed the desire to watch the world go by, explore new places or chat with fellow passengers. Designing with these activities in mind rather than simply designing vehicles as a transport utility might open up opportunities for new services, new social patterns and different types of economic activity.

Driverless vehicles will be...



Response to driverless technology

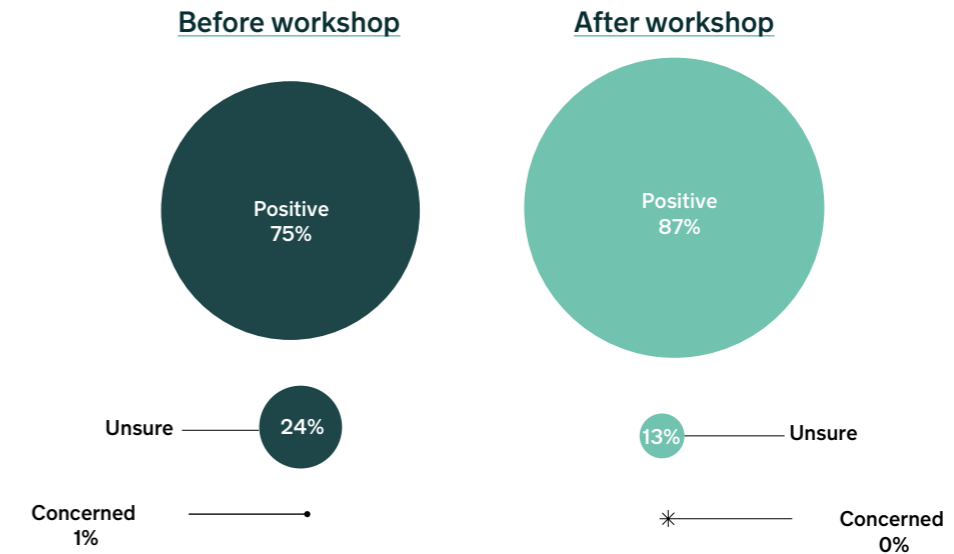


Fig 7: Insights from research held with over 100 members of the public during pre-trial workshops in summer 2016

1.4

What are their hopes and fears for a driverless future?

Interviews with experts highlighted a number of themes that were important for us to consider. These included impacts on safety, sharing and ownership, the physical environment of the city as well as a range of social and cultural issues. These themes were used to help us to plan our public workshops and provide a framework for understanding people's worries as well as their aspirations and desires.

Through the various activities that we undertook, we were able to gather a range of hopes and fears covering the main categories identified by our expert panels.

Hopes

Major hopes centred on the freeing up of time, as cities become less congested and the time during journeys becomes more useful and valuable. Participants felt that driverless vehicles would create healthier and safer city environments leading to less stress, less pollution-related illness and more social and convivial streets and journeys.

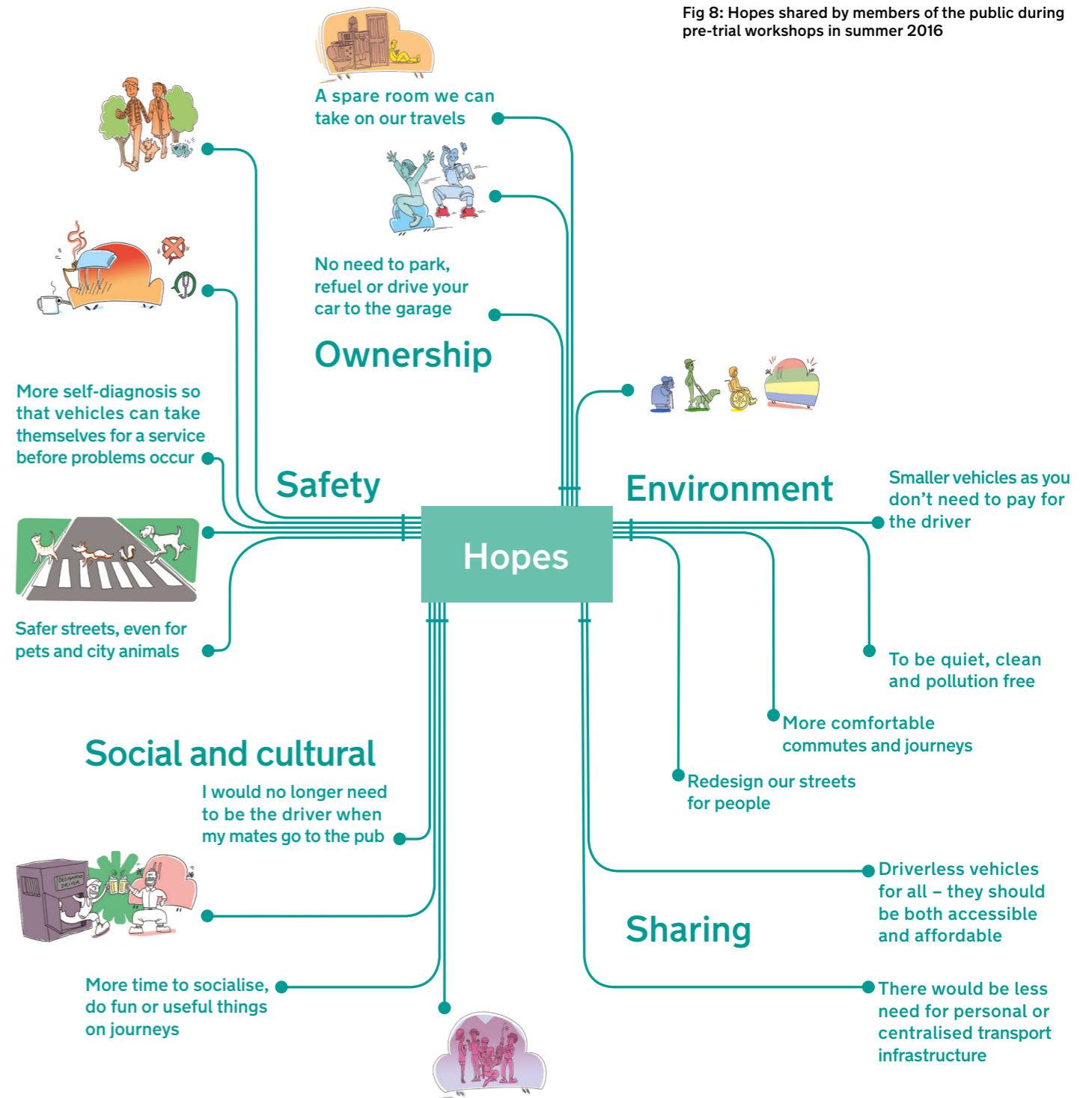
“I, personally, would ensure that everyone just use public transport, permanently. That’s my view.”

“I love cycling around London when there are few cars. The cars and the trucks, they ruin it for everyone.”

“More space, instead of cars filling up the parking spaces.”

“I no longer need to be the driver when my mates go to the pub.”

Fig 8: Hopes shared by members of the public during pre-trial workshops in summer 2016



Fears

People's concerns included the impact on employment as 'robots' take over existing jobs and economic activities, fears around data privacy, the ethical judgement of autonomous but supposedly intelligent vehicles, the loss of independence that might come when driverless vehicles control how we use the street, the challenges of cybercrime and the impact that on-demand vehicles will have on people's health as they find it easier and cheaper to get door to door transport rather than walking or cycling around town.

“AI is coming into law, into accounting, and into HR and into all sorts of areas, so lots of people are going to be without jobs.”

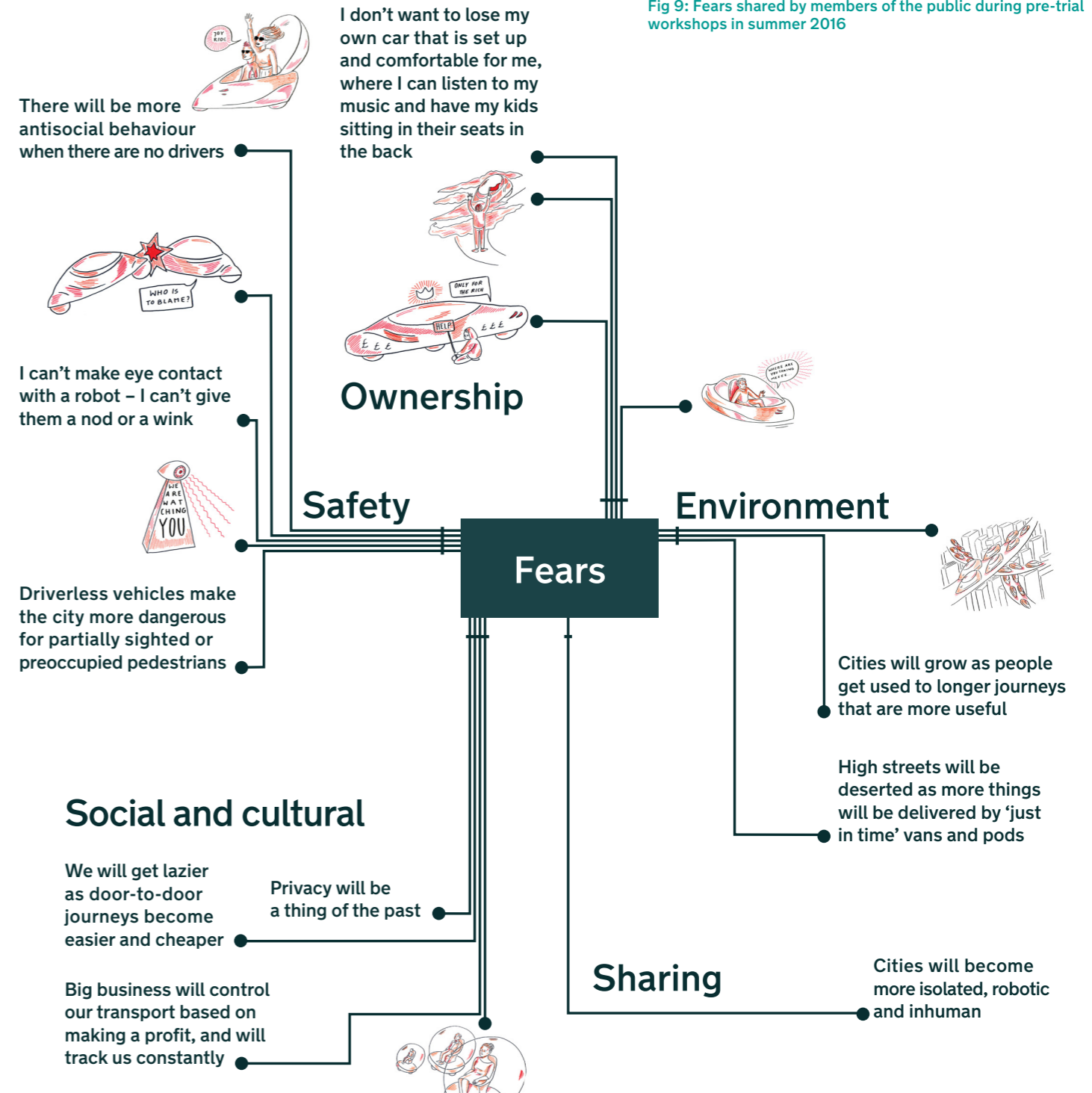
“Could meet (even more) annoying new people in your community.”

“I can't make eye contact or receive eye contact information from (robots)... I can't give them a nod and a wink.”

“I like my own car, set up for me, my music, my kids seat in the back.”

“How do you prevent big brother from tracking your journey?”

Fig 9: Fears shared by members of the public during pre-trial workshops in summer 2016



1.5.

What are the opportunities and challenges?

Each of the hopes and fears that have been discussed by participants can translate into opportunities for specific design studies that allow us to challenge purely functional requirements and create better social experiences and outcomes.

Design opportunities come from the hopes that people expressed as they re-imagined city mobility for both practical and delightful reasons.

Design challenges come from people's fears as well as from the potential excesses of on-demand mobility.

1.5.1. Opportunities

TAGS: interior, travel, commuting, work activities. How do we design shared vehicle interiors to support more comfortable, social or useful commutes? What do family friendly interiors look like? What will vehicle's look like if they support existing and new forms of work?

TAGS: on demand, digital integration, flexible transport. How can we integrate transportation services to provide an on demand service that is flexible, affordable and accessible?

TAGS: infrastructure, smart city, redistribution of space. What do future streets and 'villages' look like when shared driverless vehicles are the norm? What happens to existing parking spaces? Should they be used to increase green lungs or be redeveloped to increase the density of buildings?

TAGS: multi functional vehicles, public services. What are the public services that driverless vehicles might perform and should these vehicles be specialist or general purpose? Could they help to keep our streets clean and safe as well as provide additional support for families with younger children or older folk who need help with their shopping?

TAGS: parking, maintenance, delivery, distribution. What do the centralised or distributed services that support driverless vehicle systems look like? How and where will vehicles park, refuel themselves, be cleaned or be maintained?

TAGS: home to car. What can we learn from the design of our homes that can inform and inspire the interior of vehicles in the future?

TAGS: packaging of vehicles, vehicle typology, services. What do service vehicles look like when they no longer have to pay for or transport a driver? Will they become smaller and what will these small service vehicles look like? Mini delivery vehicles, rubbish collectors, local shuttles, building material bots?

TAGS: disabilities, partially sighted, integration. How do we integrate extra needs into general service driverless vehicles rather than creating bespoke segregated services that isolate rather than celebrate differences?

TAGS: youth mobility, under 18s, legislation, public transportation, family. How can we provide mobility for young people under the driving age who currently rely on parents or public transportation?

TAGS: traffic management, integration of services, collaboration, community. Can vehicles work together to make a hyper efficient city working in conjunction with other vehicles, traffic management systems, infrastructure and local authorities. How can they communicate with each other in a collaborative manner?

TAGS: gesture, car to human communication. How can driverless cars integrate with other forms of human transportation like pedestrians, mobility scooters, bikes and cyclists?

TAGS: ownership, subscription, hire. What ownership models could develop alongside driverless vehicles? Will we need to own a car, how will cars be paid for, could cars earn money for the owner, how will taxation of vehicles change and will car sharing become the norm?

TAGS: infrastructure. What road architecture will become obsolete with an autonomous infrastructure: speed bumps, traffic lights?

TAGS: commercial, night-life. What opportunities will emerge with a full accessible city that can be accessed 24 hours a day 7 days a week?

TAGS: congestion, traffic management. Will traffic jams be a thing of the past when faster, safer and more efficient journeys become 'standard' and accidents a thing of the past?

TAGS: infrastructure, environment, habitat, context. How can we design driverless vehicles in conjunction with the environment that vehicles will live and function in?

TAGS: social, artificial intelligence, education. What opportunities will arise from a fully connected city? Can vehicles foster and encourage better relationships between travellers? Can vehicle AI systems help travellers explore the surrounding area?

Fig 10: Opportunities developed from people's hopes during pre-trial workshops in summer 2016

1.5.2. Challenges

TAGS: isolation. How do driverless vehicle services connect with social structures to avoid an increase in isolated and inhuman city environments?

TAGS: employment, job loss, retraining. How do driverless vehicles and services create new opportunities for meaningful work and economic activity in the city? Could they form part of employability services by integrating mobility with accessibility in the context of local economic systems? Could they make it easier for people to collaborate or take part in aspects of the developing 'shared' and 'circular' economy?

TAGS: health, wellbeing, environment. How do we redesign streets and external environments to support active mobility whilst also making best use of driverless vehicle features to reduce congestion and improve the city's environmental qualities? Can driverless vehicles support active travel by integrating with cycle systems or create mixed-mode journeys that provide options for walking through parks and other green infrastructure?

TAGS: hygiene, comfort, flexibility. How can we design driverless vehicles and their interiors so they are attractive, easy to maintain and discourage vandalism or other anti-social behaviour? How might design create calm and clean environments that reduce stress and help travellers to relax when on the move?

TAGS: ethics, artificial intelligence, interaction. How do we create driverless vehicle services that use automation and intelligent software in a way that is ethical, humane and natural? How does the materiality of driverless vehicles affect our relationship with them, the services that they provide and the way we interact, engage and communicate with them?

TAGS: public transportation, congestion, traffic management, traffic flow. How do we develop driverless services that integrate with existing forms of public transport and avoid a potential increase in smaller vehicle usage and the consequent impact on road infrastructure?

TAGS: digital clarity, HDMI. How do we make driverless vehicle services 'legible' within a city in the context of digitisation and the dematerialisation of infrastructure?

TAGS: traffic management, legislation. How do we design driverless delivery services so that robotic drones and mini pavement bots don't overwhelm our skies and streets?

TAGS: surveillance, monitoring, liberty, liability. How can we balance civil liberties with the increasing level of surveillance and monitoring that will be generated through driverless technology? In a fully connected world will we ever be able to switch off?

TAGS: mega city, city sprawl. With more comfortable journeys with greater facilities, how can we prevent city sprawl?

TAGS: wealth divide, inclusive transportation, transport for all, accessibility. How can driverless vehicles be designed and operated to benefit the majority of Londoners? How can we make them accessible to the young, elderly, disabled, blind and less well off as well as the able bodied and well to do?

TAGS: managing change, infrastructure, planning, education. How can the changing environment be best managed during the transition between today's infrastructure and autonomous infrastructure? What changes will take place to the roads and pavements and how do you manage people alongside machines?

TAGS: backup, fail safe. How do we design in fail-safes for when the technology does goes wrong? At what levels of reliability should they be set and how can we ensure the highest level of safety possible?

TAGS: civil liberties, human drivers, car culture. How can we ensure car culture is maintained for those who want it? What if you own a classic car and how can those who still want to drive not be excluded from the road?

TAGS: costs, efficient city. How can the transition to driverless vehicles be achieved in a cost effective and efficient way? What is the best way to spend public funds?

TAGS: inclusivity. How can we ensure that autonomous vehicles help society as a whole rather than simply serve the needs of the companies that run them?

TAGS: Crime, mismanagement, terrorism. Can we make sure that driverless vehicles are not misused? Autonomous Vehicles, could be used for criminal or terrorist activity, used by security services to spy on people or, if Autonomous Vehicles are "too kind", bullied by pedestrians and other road users.

TAGS: social change. How can the public be introduced to driverless vehicles and what methods can be used to help educate people about the social, technical, infrastructure and digital changes that will take place as a result of driverless vehicles?

TAGS: Security, Hacking, Tracking, Safety. How do we design driverless services so that they are safe for younger people or should this be avoided to reduce childhood obesity and an increase in the number of vehicles on the road?

Fig 11: Challenges developed from people's hopes during pre-trial workshops in summer 2016

1.6.

What do people want to do in driverless vehicles?

We collected ideas from the public both in the public workshops and at our exhibition at the London Transport Museum. The public's opinion on 'what they wanted to do inside driverless cars' included things they do at home like resting, consuming media, chatting, eating or drinking; things they do in other places like bars, pubs, coffee shops and gyms; and novel ideas that came from personal interests like a 'Harry Potter' themed space. Some of the categories that were regularly highlighted included:

To get into and out of the vehicle with ease, no matter your age or ability.

A comfortable environment that provides space for day-to-day activities you might do at home like playing a game, reading, watching TV, getting ready, cuddling or even making love.

A social space that allows people to spend time with friends, family or other passengers.

A private space to prepare yourself for the day ahead or a place to wind down at the end of the day.

A flexible interior that you can personalise to meet your needs.

Facilities you might find at home like a bin, a bed, a washing area or a loo (for longer journeys).

Space to do something different like meditate, exercise or dance.

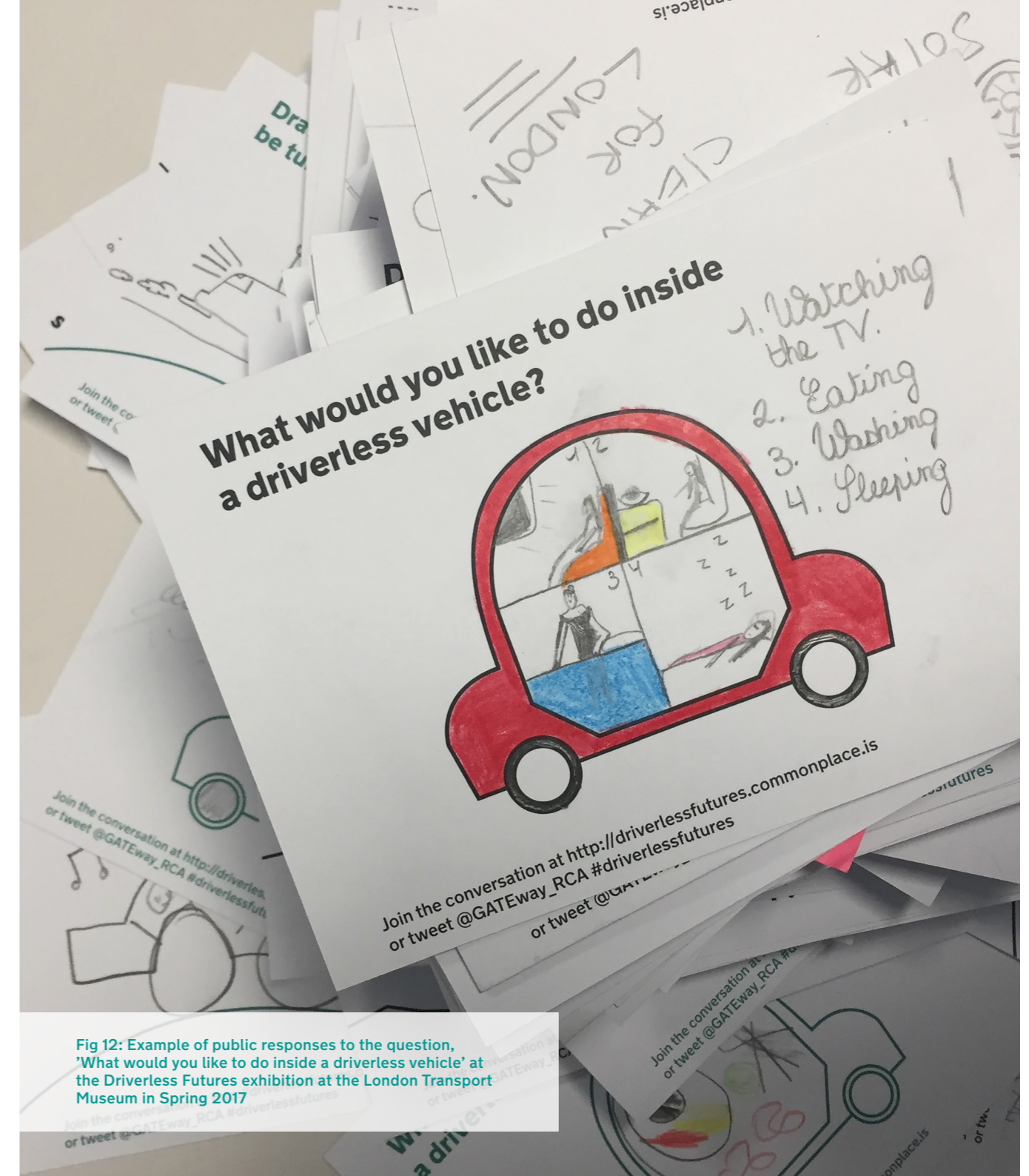


Fig 12: Example of public responses to the question, 'What would you like to do inside a driverless vehicle' at the Driverless Futures exhibition at the London Transport Museum in Spring 2017

1.7. What do people think about Harry?

We also asked people to describe what they wanted from driverless vehicles after they had experienced a shuttle journey in our prototype shuttle, Harry.

All groups were positive about the potential of driverless vehicles even if the technology today is restricted and unfinished. They believed that regulations and trials would ensure that vehicles are safe and trustworthy before they are allowed on the roads.

They saw the driverless shuttle as an eco friendly transport solution that fills the gap between active (walking, cycling etc.) travel and longer journeys where they might use buses, trains or personally owned (or hired) vehicles. The shuttle would be used to support last mile and efficient (direct) connections when you have additional needs, the weather is poor, and you are tired or carrying heavy things.

The most important issue for our travellers was 'comfort' and the definition of comfort depended on their personal preferences.

Many people expressed a preference for a practical environment with upright seats, facing the direction of travel. For some it meant being able to take your shoes off (like many European or Asian households), configurable interiors that can be changed depending on your mood, fabric seating over plastic and not having the responsibility of driving. Being able to adjust your environment

(light, glare, temperature) was important and some wanted to adjust their posture and seating if they were tired.

Another aspect of comfort concerned the idea of privacy, both within the vehicle and between inside and out. While they liked the idea of a highly open facade (a 'fish bowl, open glass roof') they also wanted to adjust the tint of the windows or blinds to control whether they wanted to look out or whether they could be seen.



Fig 13: Views of participants during research trials inside a driverless vehicle at Greenwich in Spring 2017. From top to bottom: eating snacks on the way to a party; resting after a busy day at work and sending email during a daily commute

This chapter uses our findings to create a future London that has accepted and adopted driverless vehicles and services whilst also adapting our shared environment and transport networks to make the most of this new vehicle typology.

2.0

A Future London



Part of our work on GATEway involved imagining future users and uses of autonomous vehicles, a task we approached using several methods including scenarios and personas, techniques that have been adopted by design researchers since the 1990s. In an early paper on scenarios, Jarke, Bui and Carroll (1998) identified their use in three fields: strategic management, human-computer interaction, and software and systems engineering. In some ways the questions around autonomous vehicles in GATEway lie at the intersection of all three, essentially a socio-technical system.

“Scenarios are stories. They have a setting, agents or actors who have goals or objectives, and a plot or sequence of actions and events” (Grudin and Pruitt 2002). As explained at the start of the previous chapter, a key method of design research is to imagine the real and to make it specific, not just in order to produce solutions, but as a way of testing out ideas and developing conversations around what is really needed. Rather than having some generalised concept of “the user”, “the traveller”, “the consumer” it is illuminating instead to think about particular people, in particular contexts, at particular moments in their day or night, trying to do particular things. Broadly, scenarios are imagined situations for which we aim to design, while the persona is a similarly imagined individual, not a generalised user but instead someone with individual objectives, constraints, experiences and abilities (Miller and Williams 2006).

Grudin (2005) points out that these techniques draw on a deep-rooted human ability to imagine the thoughts and actions of others. But as Marsden and Haag (2016: 4017) point out, “Personas run the risk of re-inscribing existing stereotypes,” to assume, for example, that all young users are adept with digital technologies or that all older users are relatively poor. On the plus side, as Marshall et al. (2015) point out, they can also be used to elucidate the diversity within an apparently homogeneous population. For Goodwin (2002), the whole point of creating personas is to get past our personal opinions and presuppositions to understand what users truly need. And some judicious stereotyping may even be helpful, avoiding the need to have hundreds of user-types, provided we are alert to the risks of bias and loss of rich detail (Turner and Turner 2011): personas and scenarios must respect human idiosyncrasies as well as commonalities.

When Alan Cooper first started developing the technique that became persona-based design, his personas were grounded on detailed interviews with real people, not on imaginary types (Goodwin 2009:6). Data to help decide what personas to create can also be gathered from questionnaires, focus groups, and work with design partners (Bichard, Hanson and Greed 2005). In the process, useful commonalities of need may emerge between apparently disparate groups (Bichard, Hanson and Greed 2006). And personas can be used to highlight the needs of users who might otherwise be overlooked (Marsden and Haag 2016). Lopez-Lorca et al (2014) emphasise their usefulness in “emotional scenarios” where user attitudes matter. Clearly for the GATEway project, such considerations are central: people’s hopes and fears about autonomous vehicles are just as important as their practical needs.

Focusing, as we have done, on the need to design for all, not just mainstream users, Pruitt and Adlin (2005) identify three problems that persona/scenario approaches may help to solve: designers have difficulty understanding users’ needs; those needs are complex, varied and sometimes contradictory; and, as designing progresses, the user must remain at the centre. By identifying specific user objectives, and revealing the barriers to achieving them, Siddall et al. (2011) found that personas revealed needs that had not been catered for in the generalities of a city development plan. Similarly van der Linden, Dong, and Heylighen (2019) see scenarios as a means to fill the gaps (in their case in architecture) between the processes of design and practices of use, between designers’ intent and users’ actual experience. More unusually, Leikas, Koivisto and Gotcheva (2019) use scenarios as a way of envisioning the wide-ranging ethical issues that arise at different junctures within journeys using autonomous vehicles.

Clearly, scenarios take different forms and roles within design research. Some designers use scenarios as a reference through the whole process, while others use them only as an initial stimulus (Nielsen 2002). Strömberg, Pettersson and Ju (2020) use them to construct low-fidelity pre-enactments of particular situations to see how people and things interact: the researchers and designers literally act out the scenarios. For Rosson and Carroll (2002) the whole point of scenarios is that they are a “sketch of use” which, like a sketch of a potential product, is deliberately loosely defined; they are at once concrete and flexible (Carroll 2000). For van der Bijl-Brouwer and van der Voort (2013) they should be not only flexible but also vivid. Vividness is

Nielsen’s goal too, and she asks for rounded characters rather than the standard outline personas who “could be anyone or actually no one” (Nielsen 2002:101).

Strömberg, Pettersson and Ju (2020) used scenarios to enact and understand users’ relations with autonomous vehicles; they argue that they are particularly useful when both parties to the intended interaction, such as human and vehicle, are active rather than one side being merely responsive. They emphasise the benefits of concretisation that we have discussed before: vaguely imagined actions can more effectively be designed-for once they are made real. Goodman-Deane et al. (2010) found them effective in fostering designers’ empathy with user needs, though not well suited to presenting detailed technical information about, for example user disabilities. This is confirmed by our own extensive experience of design for – and with – people of all abilities both physical and cognitive: there are no short cuts to deep detailed knowledge here.

Emphasising that scenarios and personas are only a part of the toolkit of design, Siddall et al. (2011) concluded that personas may work most effectively when used in combination with other user-centred design tools, such as participatory design. That way real users can actively contribute, rather than their actions being imagined. De Voil (2010) emphasises the need to return regularly to the real world and real users: “Real people have real, messy and inconvenient problems.” Worryingly, Grudin and Pruitt (2002) note that in their extensive experience “often, scenarios are used in place of real data.” Our own use of scenarios was complemented throughout by our direct engagement with the potential beneficiaries (if such they turn out to be) of autonomous vehicles.

We have already noted some limitations of personas and scenarios that we have avoided or worked around. We unashamedly made up our personas, a practice that concerns some, such as De Voil (2010) who complains that a persona does not capture in any statistically valid way a set of data points. Siddall et al. (2011), however, decided what personas to develop based on the known proportions of types of users in the city under study. Even where a quantitative basis for the choice of personas may be difficult to verify, many argue that the qualitative benefits of the technique can justify its use (Putnam et al. 2009). And as Grudin and Pruitt (2002) point out “When attracting hundreds of thousands or millions of people is the goal, finding ‘representative’ participants is a challenge”. The people who will be affected one way or another by driverless cars are arguably everyone, rather than the tidy target group often associated with a specific future product.

Rather than use scenarios to represent pseudo-realistic people and situations, Nilsson et al. (2019) used “provocative utopian and dystopian scenarios of future autonomous systems” to elicit new reactions and insights that might otherwise have remained unspoken. This approach was pioneered by Bødker (2000) who constructed two detailed scenarios around the use of a proposed technology: a cheery utopian vision and a nightmarish, dystopian vision. As Grudin and Pruitt (2002) point out, this emphasises the weakness of using any single scenario: it would not be anchored to reality strongly enough to be more than an argument. In another key part of our work on GATEway, we focused on using utopian and dystopian views to elicit new thinking from both experts and the public (see 7.4.2 Driverless Futures Exhibition).

As in the present report, personas and scenarios can be a useful way of conveying “what if” situations to a range of audiences. They enable rapid communication about usage possibilities and concerns among many different stakeholders (Rosson and Carroll 2002). The whole team can cluster around the persona, using her/him as a focus for shared debate, in a way that would be impractical and unacceptable around a real user. They are a supplement to real users, not a replacement for them. They help an outside audience, too, to understand the circumstances, needs and other factors that gave rise to a proposed design. In a survey of methods by Li et al. (2016) scenarios are part of a relatively small group of techniques that benefit the designers, the service providers, the users and other stakeholders. But personas are not immune from the usual tensions of multi-stakeholder working: some individual personas, indeed the whole method, may become victims of disagreement about the main agenda and approach (Rönkkö et al. 2004).

Grudin and Pruitt (2002), perhaps optimistically, see personas as forcing “designers to consider social and political aspects of design that otherwise often go unexamined”. If scenarios facilitate “goal-directed design” (Cooper 2004: 149-159) it is essential to remember that users have many goals at different levels and timescales, sometimes in conflict with one another (get there as fast and cheaply as possible; save the planet for future generations). And that the users’ goals, even taken collectively, do not necessarily define what should be done. As with other user-centred design methods, these methods carry the danger that we will end up designing for the world as it is now rather than as it might be, making design politically and socially unadventurous, something that would have been a failure in any project like GATEway, so bound up with the future of society.

2.2 London 2035 – setting the scene

In 2035, London has remained an influential and important city, although many of the larger cities around the world will grow in status and quality. The population has grown to over 10 million (~1.5 million more than 2015), while Crossrail 1 and 2, together with HS2, will bring millions of more people within 30 minutes of central London. The number of over 60s in London will reach almost two million (a 50% increase) and older Londoners will be the fastest growing demographic across the city. Socially, London will become more diverse and inclusive although there will still be high levels of relative poverty and inequality despite greater levels of political oversight that comes with increasing regional democracy.

Climate change will affect London despite global efforts to reduce emissions. There will be more frequent floods and many older Londoners will be affected by heat stroke during the summer. The Mayor will continue to invest in natural and technical infrastructure to reduce the negative impacts: from the London National Park City to street bioswales and cooling systems on public vehicles, buses and the underground.

In a preferable future, the mayor will have extended the ultra low emissions zone to the M25 and implemented an Autonomous Zone (The AZ ring) in central London. All vehicles within the AZ ring will have to drive autonomously unless their drivers pass advanced driving skills tests, but most people are happy to let go of any remaining steering wheels and let AI take the strain.

While London will have survived a number of economic upheavals by becoming part of the ‘Global 50 Circular City Economic Region’, many Londoners will need to reinvent themselves as carers, creatives and craft-makers to combat the rise of the ‘Artificial Intelligence’ (AI) economy, which continues to impact on traditional white and blue collar jobs from AI-assisted lawyers and AI-augmented marketing and design companies to autonomous taxis, delivery systems and driverless rubbish trucks.

2.3 An introduction to our future families

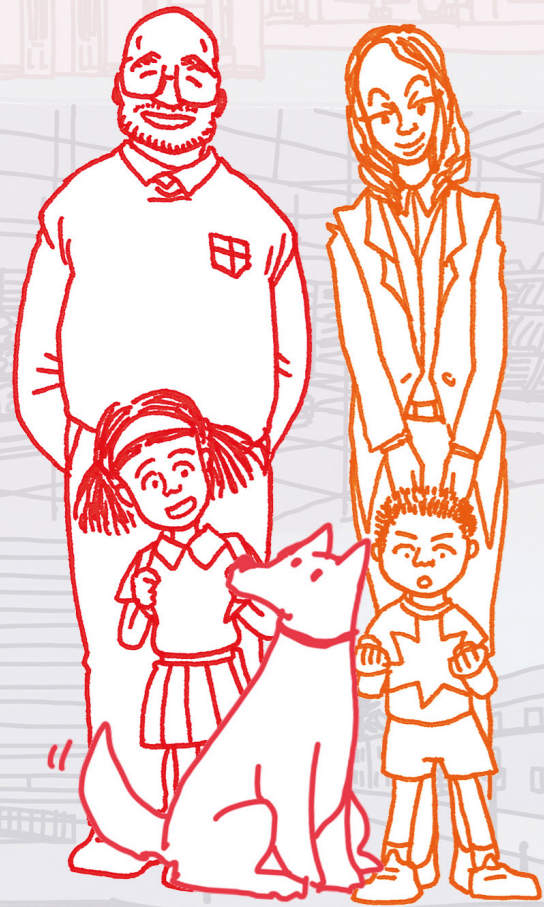
In order to describe a preferable future that makes use of autonomous vehicles that meet people’s hopes and, to a certain extent, overcomes their fears, we have developed four scenarios that introduce different types of Londoners, supporting inclusive and diverse needs rather than ‘average’ requirements.

These characters live in a future London that in many ways is similar to the London of today. People have their likes and dislikes; they live in a range of buildings, both old and new; some are wealthy, some relatively poor; they have physical challenges and a range of attitudes. But they have all taken to the idea of driverless vehicles as part of their everyday life, and these vehicles, in parallel with walking, cycling and existing public transport represent the major modes of mobility in inner London.

We developed detailed story lines to help us to investigate the range of vehicles that they might use. We can only show a summary of their future lives in the context of this publication. These storyboards also give us the opportunity to introduce some of the driverless vehicles and services that we have developed as part of our research.



Fig 14: Illustrations of our future Londoners. Clockwise from top left: Michelle and her family; Steve and Simone, an older couple; Jason, a teenager who is short of cash; and George, an active Londoner who also uses a wheelchair



Michelle, Sean, Rachel and Billy live in a 5 bed Victorian semi in Ladywell, South East London. Michelle is a 45-year-old lawyer who works for a digital education and publishing company. Sean teaches at a local primary school.



Steve and Simone are in their 70s and both have French roots, although they have lived in London together for 40 years. They have a small flat in Blackheath and their daughter, Charlotte, lives nearby with her 6-year-old child, Lola, and her partner.



George is 28 and lives near Stratford and works in Greenwich. He has a wheelchair but is active and loves to play basketball with friends. He has a subsidised driverless car that he rents out to reduce his costs and an assisted motor wheelchair that gives him much needed freedom.



Jason is 16 years old, is studying sports management at college and lives with his parents in the Isle of Dogs. He's strapped for cash, works part time in a pizzeria and is constantly running between home, class, the football pitch, his friends and his evening job.



Michelle calls her AV Family to home from the local parking / charging area, while Sean and the kids walk to school, passing the circular service material collection bot and street cleaner on the way.

Sean orders the local Flexibus to take him to school. It has fold out tables so he can do some final marking on the way in.



Simone and Steve still like shopping but use the Sharewell pod to send their groceries home.

Steve goes for a check-up in the mobile health-2-community van that takes health teams to the local area, helping everyone to feel connected as well as saving time and money.



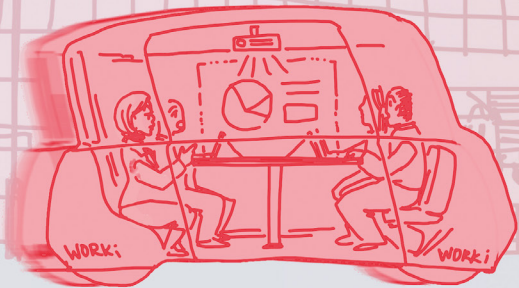
George's Oasis car is fully accessible making it easy for him to use and access in his wheelchair. He can control it by voice or his mobile app.

Even though George has a car, he still uses the DLR to get to work as it's quick and inclusive. He rents out the Oasis during the day, when he doesn't need it.




Jason's late for school and running for the bus...


He's forgotten his boots again! His mum sends them to him using a sharewell pod.




Michelle and her colleagues take a work-e taxi across town. They finalise their presentation and have a video conference en-route.




Sean and Michelle are avid gardeners. They have propagated some plants and Sean uses a Sharewell pod to send them to friends.




Jason's dad is installing solar panels at Michelle's home. He uses a shared white van to transport equipment and cycles across the river instead of sitting in traffic.




Simone uses an electric assist scooter that reminds her of being young.




Simone loves playing with Lola. The streets are much safer and cleaner so she doesn't worry as much about pollution or accidents.




Steve uses the Flexibus to make local journeys. As a senior citizen with arthritis he can book the bus to provide door-to-door travel within the neighbourhood.



George can share his oasis with friends - something he loves to do - or hire it out to cover some of his travel costs.



George uses his PABot to help him carry shopping. If he didn't have one he might be stuck at home relying on internet groceries.

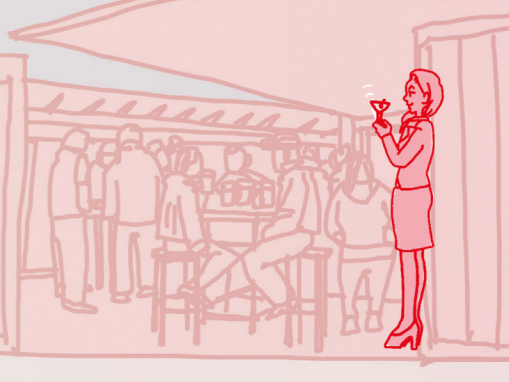


Jason's late for practice again so he takes an M-step to the pitch. Its motor assisted and can even run autonomously if you need help navigating.



Michelle has sent her AV family to pick up her elderly parents. It knows their personal preferences and drives carefully en route.

Later that evening Michelle is out with friends in North Greenwich...



Simone volunteers to be a concierge for Lola's Skoolbus that can be used to pick up and drop of kids and has eliminated school run traffic.

Steve is in the local pub watching the cricket with friends but Simone calls him to say that they are going out with friends....



George and his PABot are on their way home after shopping. If he has space he happily stops to share the journey with local passengers.

George starts to feel unwell on his way home from a game of basketball. He asks the Oasis Assistant to connect him to 999. In extreme situations the assistant can communicate directly with emergency services.



Jason has joined some older friends who have booked a Z-box gamer for a journey into town. On the way they play 3D games projected onto the surrounding city.

Jason loved the Z-box gamer but is annoyed that he is still under-age and can't use a driverless vehicle unaccompanied until he is 18.





Michelle is feeling worse for wear. She decides to take a single person recharge home instead of the bus. She can set it up in relax mode with her favourite music and lights dimmed...

As the recharge arrives home, Michelle is gently woken from her snooze. Once she is dropped off, it goes to a local charging point and then heads off to pick up another late night reveller.



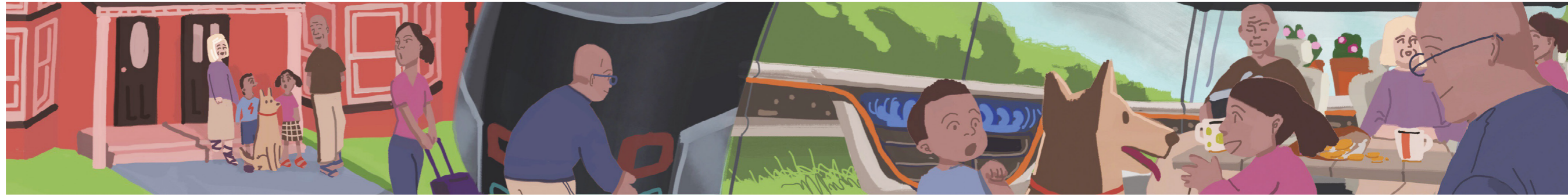
George arrives at the local A&E where paramedics have been alerted to his arrival. Fortunately he starts to feel better but he doesn't fancy going home alone so they arrange for a friend to join him for the journey home.



After work, Jason plans to walk home along the river but he gets an alert on his phone that the new autonomous river bus has free tickets for students today. He settles back with a slice of pizza and enjoys a well-earned rest after another hectic week.

The weekend...

The AV Family is big enough for the whole family so they load it up for a weekend away. The grandparents sit at the front discussing plans with Michelle, while the kids argue over whose lap Fido can sit on and Sean tries to calm them down with treats. Only an hour left before they arrive...



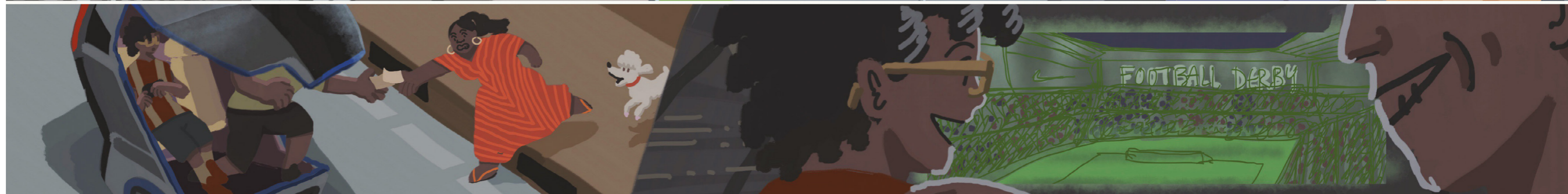
Steve and Simone meet some old friends on the weekend and hire a Workie to take them to Bromley for the day. While Simone rests, Steve watches the cricket with his old friend and marvels how things have changed since he was young...



George has taken the car to his mum for a day in the countryside. She's really pleased to see how independent he is now that he has his new Oasis and they talk about his plans to explore more of the country now that he has wheels...



Jason and his dad take a two person city zip to the football match at Stratford. It's an opportunity for them to catch up with each other and share one of their shared passions with a little bit of privacy. They watch the build up to the game as they approach the drop off point and get an alert from the zip as the sound of the crowd grows in the background...



3.0 Vehicles and Experiences

In this chapter, we look at the vehicles and services that appeared in the Future Stories. These vehicles help people get around London, move goods around the city and improve the quality of London's infrastructure and environment.



We trace briefly here some of the key concepts that underpin the vehicle design research component of GATEway, including shifts in consumer behaviour and trends towards integrated mobility. Several of these concepts are discussed more fully in the next chapter and in 8 Future Research Opportunities.

Vehicle design now lies at the intersection of multiple disciplines, with radical change not only in the technologies of mobility, but also in the commercial, social and cultural models with which they interact. Where previous university and corporate research has tended to focus on mechanics, engineering solutions to perceived problems and iterative developments leading to incremental market advantage, we have addressed questions that are more subtle and complex, and that require human-centred approaches which are designed. While previous research has tended to concentrate on the movement of people and objects, the urgent need is to re-focus on the journey, the experience, the design of services and systems, and the complexity of the infrastructure and interactions that mobility in modern advanced societies entails.

The RCA has for more than 40 years led thinking in vehicle design and has created the most successful designers and design executives in the automotive industries around the world. At the start of that period, vehicles were regarded primarily as manufactured objects and desirable consumer goods. Post-war increase in spending-power had led in ten years after 1950 to a doubling of UK household car ownership (Liebling 2008). Whereas in

1950 more than 80% of households were without a car, today that same proportion own a car or van (ONS 2017). Yet changes in the growth of ownership are occurring. Car driving as an aspiration is declining: while 83% of English men in their twenties held a driving licence in the early 1990s, in 2014 the equivalent figure was 63% (Metz 2016). Technical and conceptual innovation may cause vehicle ownership to be replaced by MaaS – mobility as a service (Hietanen 2014, Jittrapirom et al 2017). Complementing this shift from owning things to using services is an increased emphasis on the value of experience and the growth of an ‘Experience Economy’ (Pine and Gilmore 1998).

The research question: ‘How does design help to increase the acceptance and adoption of driverless vehicles in urban environments?’ led us to employ a variety of research methods and tools. These were used to enable us to better envisage, understand and frame the problems and possible solutions in relation to the research question. The research outcomes are tangible design concepts with potential to be integrated into future vehicles. The future driverless vehicles in this chapter could become future archetypes. They embody user-centred design expressed through a series of typologies that reflect the diversity of mobility solutions made possible by driverless technologies.

An outcome from our design research is the potential wide range of scale in driverless vehicles, which can help to respond more adequately to people’s needs. The logistics of moving goods around the city will become more agile and connected to smart systems, developing beyond systemic coordination through RFID (Eckhardt and Rantala 2012) to user-oriented approaches to complex and

conflicting needs (McFarlane, Giannikas & Lu 2016) and service-based models (Traganos et al. 2015). Small autonomous mobile devices also might be useful to assist people with disabilities or who simply need to carry heavy shopping, and encourage walking and cycling. The opportunity to make streets healthier, safer and more pedestrian-friendly must be a focus of future autonomous vehicle designs (see 5 Environment and Infrastructure). New vehicle design may establish different ways of connecting private and public transport. Our research investigates new transport modes that will be part of London’s future transport network and that of other cities, such as the Flexibus, designed as a community based shared vehicle.

The research also looks at what people will do inside vehicles once they are not driving: both the reflection and the making of new attitudes and habits. Vehicles are reimagined as spaces that move, rather than vehicles with internal space. The passengers’ activities will be a key factor that defines the shape of the body and the usability of the vehicle (Mausbach 2010). How can the interior of an automated vehicle be redesigned to increase the social experience within? How can interactions with the outer world be enhanced, in order to take part in productive or social interactions (Pettersson et al. 2016)? Supposing a MaaS model, a more luxurious car could be the choice for the family weekend, and a cheaper, simpler car could be used for commuting (Jorlöv, Bohman & Larsson 2017). Though two surveys produced different user preferences for activities in driverless cars, reading a book and watching TV/movies came high in both (AIC n.d.; Carnegie Mellon 2015), and high digital connectivity was valued. A number of impediments have been discovered to the much-touted autonomous mobile office

(Sivak & Schoettle 2016). Nevertheless, our Workie design presents a potential new taxi layout, which is a co-working space as well as a mobility device. Our Health2Community vehicle (section 3.2.8), shows the creative possibilities and benefits for vehicles designed as moving spaces, improving health care and public services, also opening many perspectives for market and culture – a driverless future aligned to a dynamic and sustainable city life.

As discussed in Chapter 7, the designs offered here are not necessarily intended to point in one direction for the future, but instead to open up a range of possibilities for argument and deliberation. They were important stimuli in the exhibition, workshops and other engagements at the heart of the RCA’s research.

3.2

Helping people get around the city

Londoners still make use of the city's extensive public transport network and all residential and commercial streets have been designed to encourage walking and cycling as well as dwelling, sitting, chatting, eating or shopping.

The public transport network has been extended to support larger numbers of people and to be more inclusive. It also makes use of smaller autonomous vehicles that support different community needs.

Privately owned vehicles and service providers supplement public transport. Some of the private vehicles are used exclusively by individuals or families but many people decide to share them with friends or the local community either as a favour, to reduce the cost of ownership or to make money. This reduces the number of vehicles that need to be parked on streets and increases the relative efficiency of London's road network.

Digital services and electronic systems help people to make better use of walking and cycling infrastructure. Pedestrians and cyclists use integrated transport planning software to show active or sustainable transport options. Novel software shows healthy journey options and suggests places to pick up food, goods or services en route.

London provides an inclusive e-oyster travel service that ensures that walking, cycling, public and shared transport options compete

on a level playing field with for-profit platform providers. It integrates this information into a handy travel companion that can be viewed on mobile devices or on e-screen posters that have been integrated into sitting areas next to bus and vehicle-sharing stops. The screens show the local area indicating amenities together with walking and cycling routes as well as estimated times for other public or shared transport solutions.



Fig 15: People getting around London on foot, by bike, in public transport or taxis and in private cars

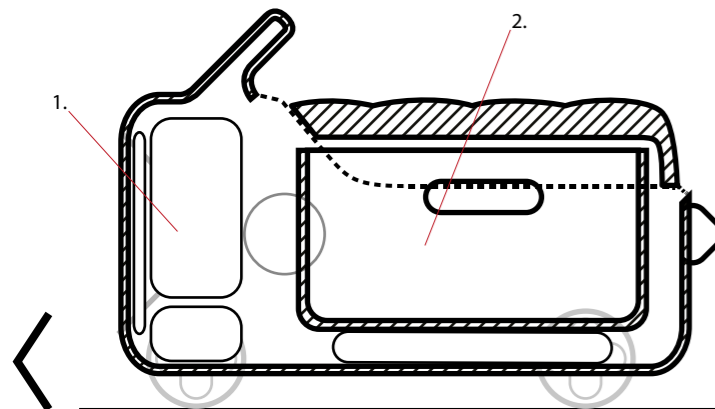
3.2.1

PABot

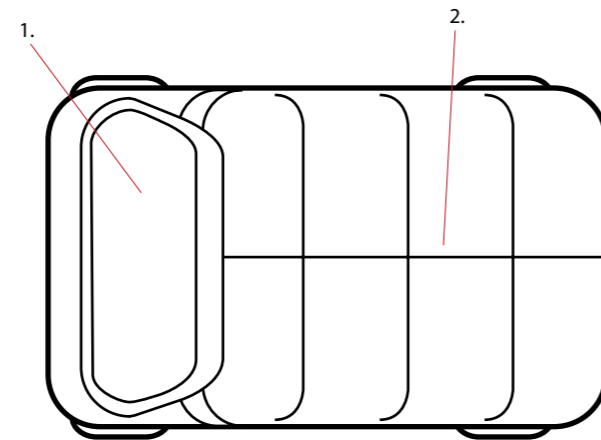
– an inclusive personal assistant

The PABot is a mobile guide for those who have additional needs or struggle with heavy shopping, including people with visual, mental and physical disabilities.

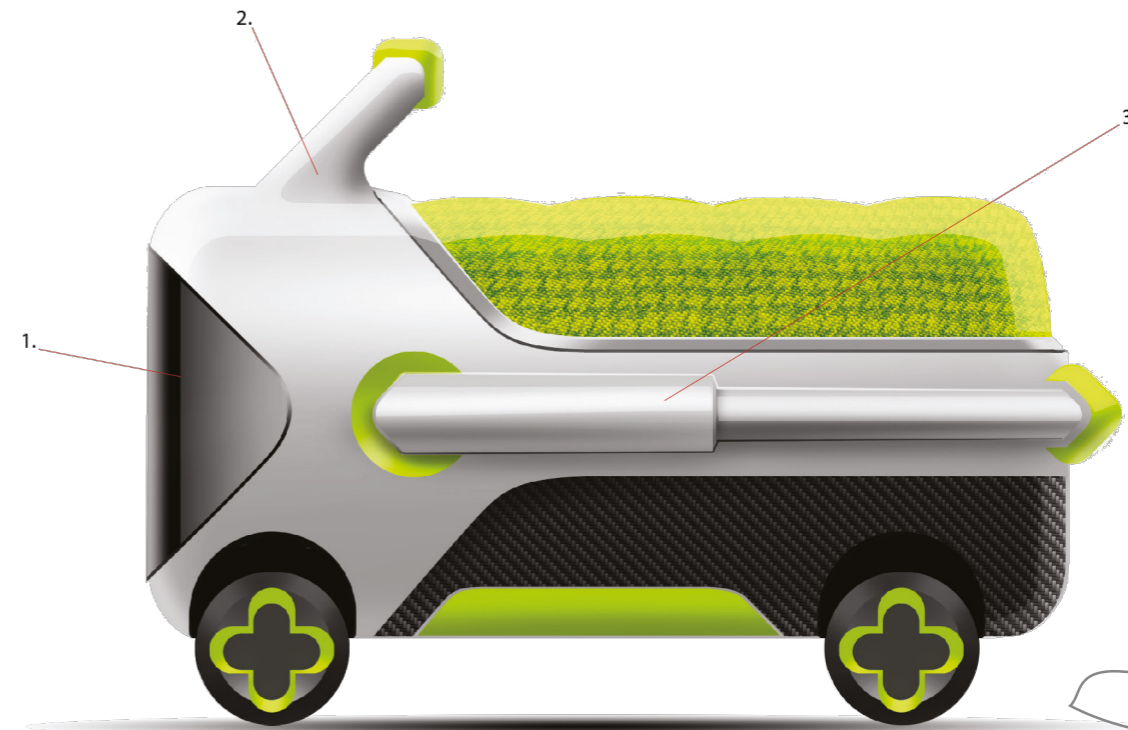
As well as guiding you along your journey it can carry your bags and be connected to a variety of digital support services via your mobile device. It can include a seat for your child, as it's often very hard for those with disabilities to handle a buggy when they are out on their own. The PABot can also attach to your wheelchair and push you to a destination that you have specified with your device, or offer you full control to make getting around the city a breeze.



1. Battery, motherboard, electric motors
2. Cargo basket



1. Handle with cup holder and device charging point
2. Cushion childrens seat



1. Sensors and navigation cameras
2. Can be programmed to lead or follow
3. Telescopic guide stick

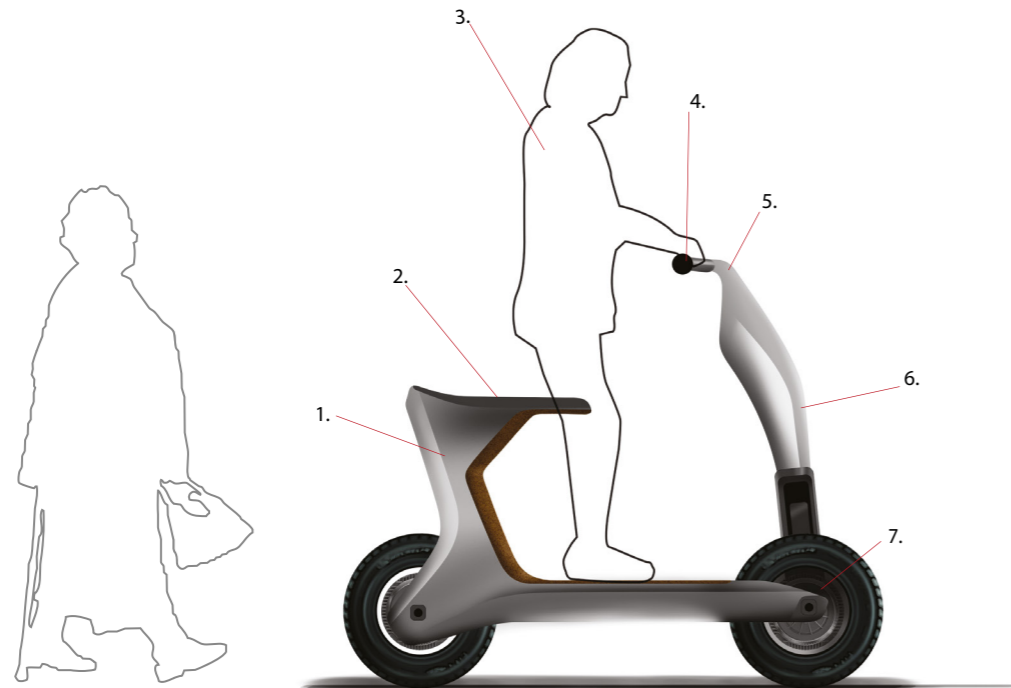
Rather than drag you forward or follow you from behind, the PABot moves along beside you rather like a guide dog. You can attach a lead to it or get nudges via a wrist bracelet that pulls gently to indicate directions. It can also 'woof' if it senses that you feel threatened or it wants to call your attention to something.

3.2.2

M-Scoot and M-Step

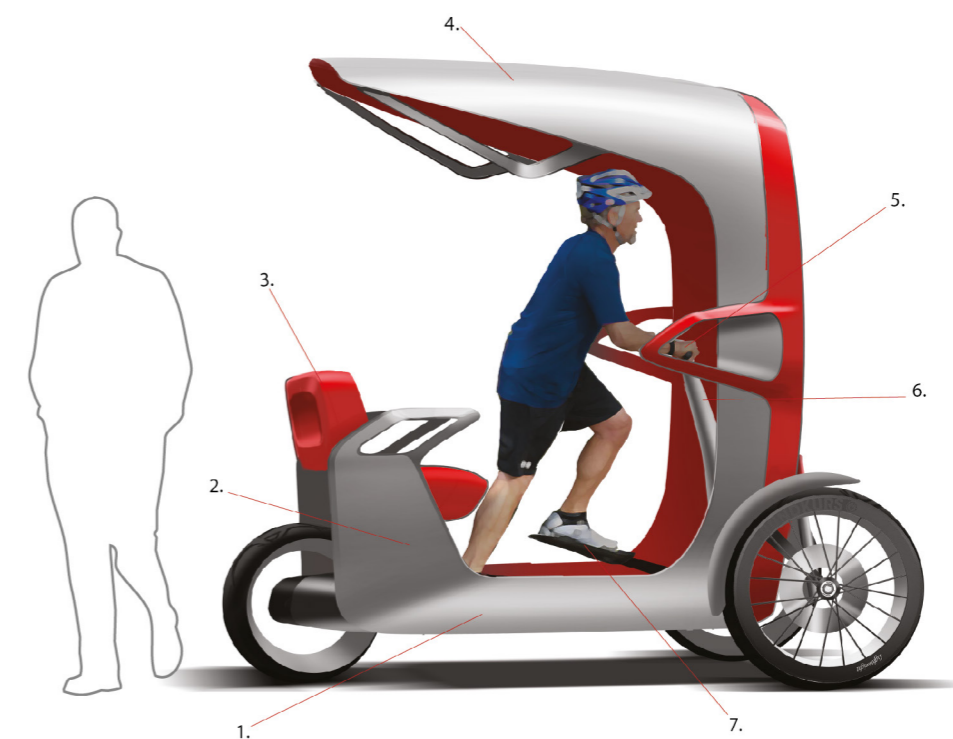
– inclusive and personal mobility

Small autonomous vehicles sit between cycles and motorbikes. The M-Scoot and M-Step platforms provide everyone, including those with reduced mobility, a semi-autonomous ride that can be supplemented by power from scooting or stepping as you ride along.



1. Driverless capabilities offer potential door to door service
2. Adjustable seat to suit standing or sitting riders
3. M-Scoot tilt allows riders to gently exercise their core
4. Grab bars control speed and direction
5. Mobile devices provide guidance and local information
6. Stability bar
7. Wheels contain hub motors

M-Scoots are hired from docking stations that also act as charging points or they can be summoned closer to your point of departure using in-built navigation systems. This is particularly important for the service provider as it means that M-Scoots can redistribute themselves around the city based on demand.



1. Electric motor and battery
2. Small storage space
3. Seat with backrest
4. Rain cover
5. Control bars
6. Stability bar can also be used for pulling exercise
7. Elliptical exercise footrests.

The M-range of small vehicles can switch between user-driven and autonomous mode so they can guide visually impaired people through busy intersections or let older people rest for part of the journey. The autonomous mode is there to assist with riding to prevent the rider from crashing and to park or move the scooter when the rider gets off. Lights and a built in 'hooter' communicate intent, turning etc. A retractable rain cover provides additional protection in wet conditions and steering is achieved through an electronic rather than mechanical system.

3.2.3

Recharge

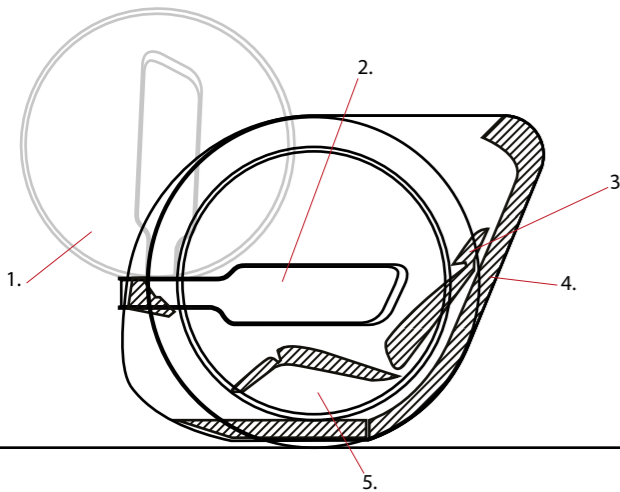
- a comfortable private space to recharge

The Recharge pod is a one-person Autonomous Vehicle designed to support city centre commutes particularly outside of peak hours. Pods are stored in conveniently located city centre dispatch centres integrated with transport interchanges; and are serviced and managed by a taxi service that specialises in smaller Autonomous Vehicles.

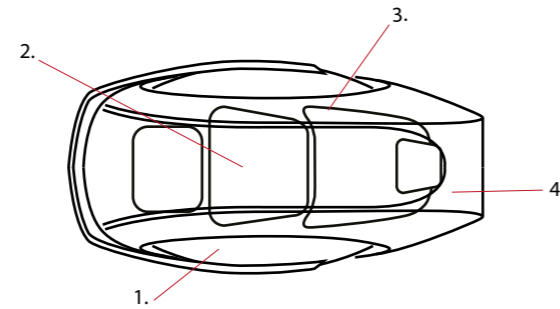
The pod has two large wheels to make it easy to park at right angles to the pavement. Once

inside you can read, nap or watch media on a heads-up display built into the windscreen. The Recharge contains a single fully adjustable reclining seat with orthopaedic features. You can set the interior ambience including music, aroma and lighting and, if you nap, the seat will rise up, interior lights will brighten and a gentle alarm will play so that you are fully awake before you reach your destination.

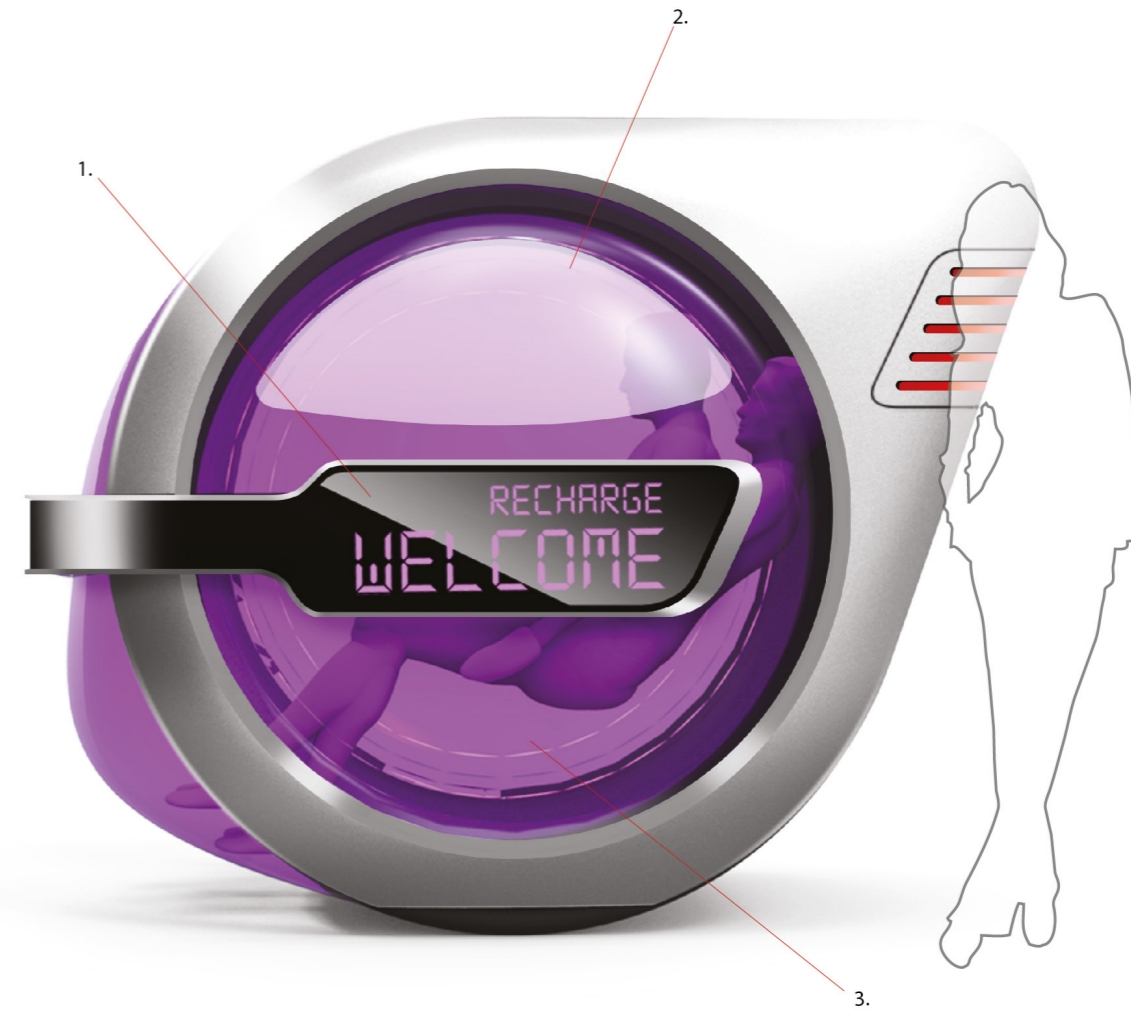
There is space to store things underneath the seat and pods can be adapted to perform other city services including delivering medical equipment (health pod), traffic management (police pod) and mobile cafe (coffee pod).



1. Large butterfly door
2. Entertainment system and temperature control
3. Fully reclining seat
4. Passenger cell and moulded L-ion battery
5. Under seat luggage space



1. Adjustable opacity glass to simulate night during the day
2. Fully reclining massage seat with foot rest
3. Entertainment system & temperature control
4. Glass roof



1. Passenger communication display
2. Butterfly door
3. Space for light shopping or small luggage

Like other shared vehicles it has materials and sensors to stay clean for longer and to identify when it needs to be serviced. Some providers have a rating system that restricts passengers based on online data while others encourage open usage and provide a place for rough sleepers to rest at night provided that they keep it clean and tidy after use.

3.2.4
City Zip

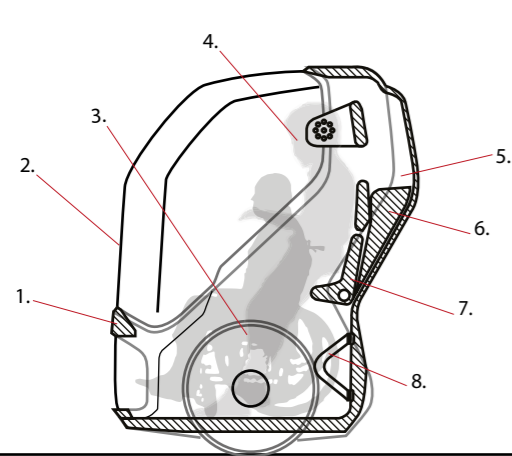
- from A to B for 1 or 2

City Zips are two-seater taxis designed to take people on short trips across town or to connect with larger public transport. While private hire companies own many, they are often subsidised by local authorities to help residents with disabilities or additional needs so they can access services or get around more easily. They offer door-to-door services and are easy to access from the pavement as they park sideways to the street and open at the front.

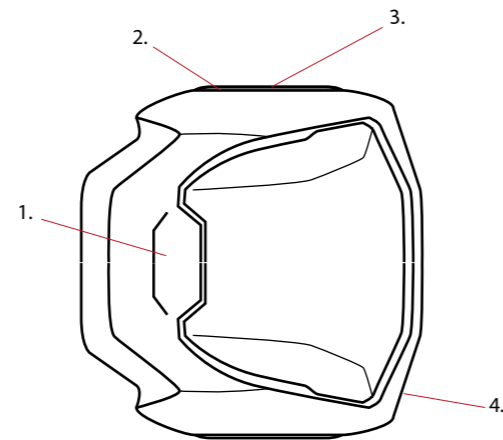
The Zip offers space for two people on perched seats and the interior can also support a wheelchair and an accompanying passenger. A novel feature of the Zip is that

it balances like a Segway and only has two wheels making it a relatively compact vehicle that moves at a sedate pace along the street.

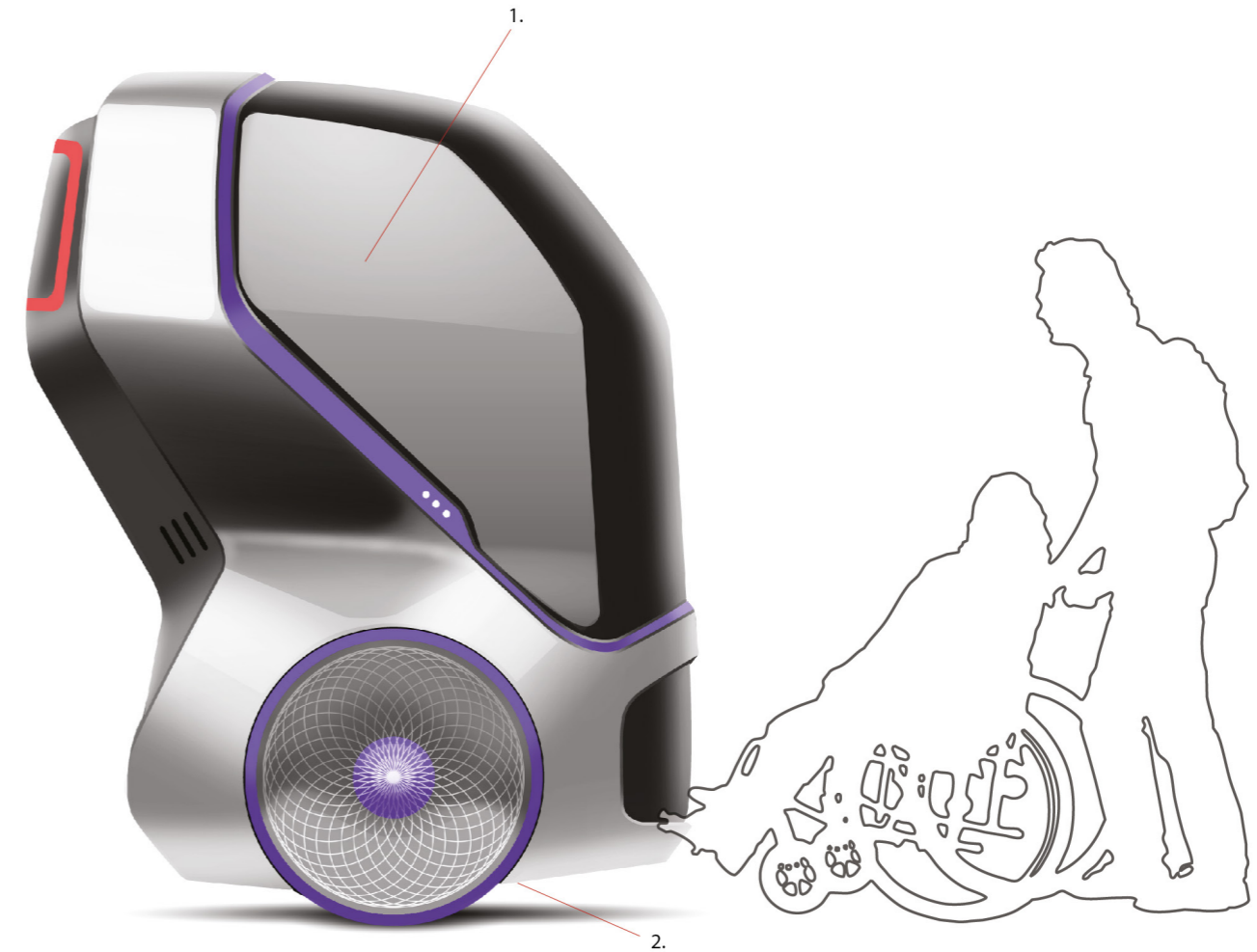
Zip seats have safety straps, headrest and fold down armrests. There is also a lower perch for a child or space for a pram. The Zip communicates intention through lights and zippy sounds and can offer privacy with adjustable tint or mirror windows, which are open-able for ventilation. Some zips have in-built screens for entertainment and are controlled via your personal device to keep costs down. As with all Autonomous Vehicles there are emergency stop facilities that can be pushed or activated from your personal device using voice control.



1. User interface/info display
2. Multifunctional LED glass house
3. Adequate space for 2 passengers/1 wheelchair user and carer
4. Personalised sound or descriptive audio
5. Parcel shelf
6. CPU/GPU and controllers
7. Adjustable perching or flip-down fully seated bench with safety belt
8. Wheelchair fixing points



1. Exterior vents for natural cool air flow
2. Full Control System support with tactile buttons
3. Descriptive audio for visually impaired
4. Front windscreen can turn into mirror for getting ready



1. Single door frame with glass house and lower display
2. Tilting floor and stabilisers depending on terrain

Zips use public charging infrastructure and are cleaned by a roving maintenance team. The dock-less system allows them to use big data to identify demand and support peak city experiences such as sports or music events. A significant proportion of zips are stored at the edge of the city where they can be fully charged and cleaned. This allows them to serve the outer zone where there are fewer public transport options.

3.2.5

Workie

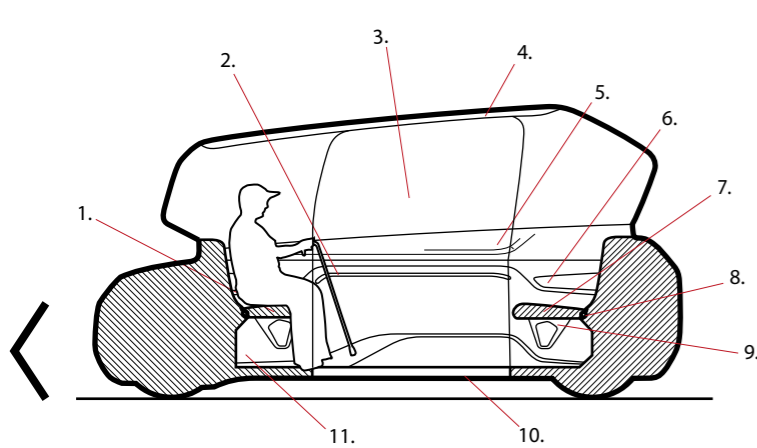
– working together while crossing town in comfort

The Workie is a 6-person taxi designed to take small groups of people across town, to rail interchanges, hotels or out to the airport.

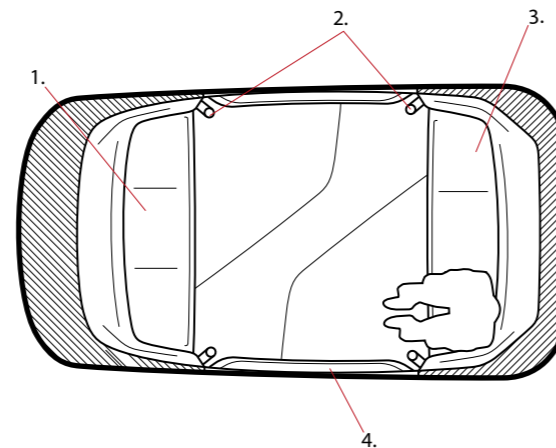
People order a Workie via an app and pick it up at the nearest drop-off point or central pickup area. While many are owned by fleet providers, TfL encourage ownership and maintenance by ex taxi drivers who also act as concierge and guides for people who need additional support including those with disabilities or tourists from out of town.

Like modern taxis Workie let's people know that it's for hire and can be hailed from the street or via an app. Once hailed the vehicle pulls over to the nearest designated drop off point and the door can only be opened by the person who booked it.

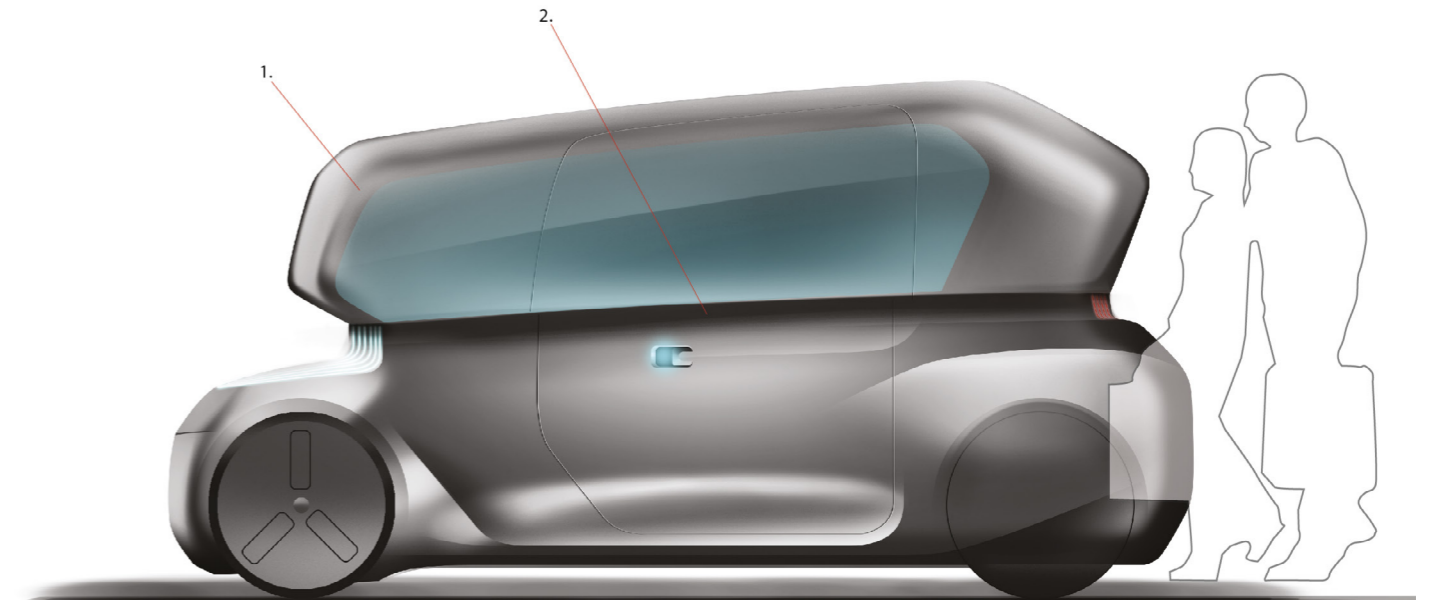
The Workie has a comfortable fixed bench seat and fold down seats together with a foldable table for work or snacks and a large storage area inside the vehicle for luggage. It's accessible through a large sliding door on the pavement side and a ramp can extend for prams and wheelchair users.



1. Rear facing seating for 3 people
2. Grab rail
3. Screen display in windows to show travel information
4. Hearing loop
5. Control panel
6. Fold out tables
7. Forward facing seating for 3 people
8. Hinge point to fold up seating
9. Luggage spacers /wheelchair supports /buggy supports
10. Wheelchair ramp in floor
11. Counter levered seats



1. Bench seating for 3 people
2. Grab bars
3. Bench seating for 3 people
4. Entrance and exit area



1. Larger windows for good visibility
2. Entrance and exit area

A screen is provided for travel information, live updates, news or entertainment and you can also present to the screen from any device so that work conferences can continue on the move. Workies are stored in depots near to major transport interchanges and owners can either maintain them in these depots or hire a cleaner to do this. Despite the innovations in prediction and demand management, long lines of Workies still queue outside mainline train stations waiting to be picked up.

3.2.6

Familie

– a vehicle to improve family wellbeing

The Familie is a fully featured family vehicle that can accommodate up to 6 in comfort. It is often owned or leased by an individual family but some people share them and they can also be rented or be part of a car-sharing service.

The Familie, like all modern autonomous vehicles, is electrically charged using an induction charging system and has PV cells built into the roof lights so that it can continuously top up charge during daylight hours, feeding into the grid or the built in batteries depending on need. It has a six-seat interior that can be configured

in a multitude of ways to meet the needs of a growing and changing family. The base interior includes two three-seat sofas with individually adjustable seats. Sofas can face inwards or outwards and each seat can recline and includes footrest, headrest and folding armrests. A large amount of storage space is available and accessible both from the interior and via a rear boot, some of which can be accessed by a smart shopping bot or delivery person so that things can be dropped off securely in the vehicle if the owner wishes. There is space inside for a pram or a wheelchair and both can be locked in position so that the vehicle can move without needing to get into a seat. There is also space for things to dry and a series of optional extras to suit a wide range of families. These include a drop-down

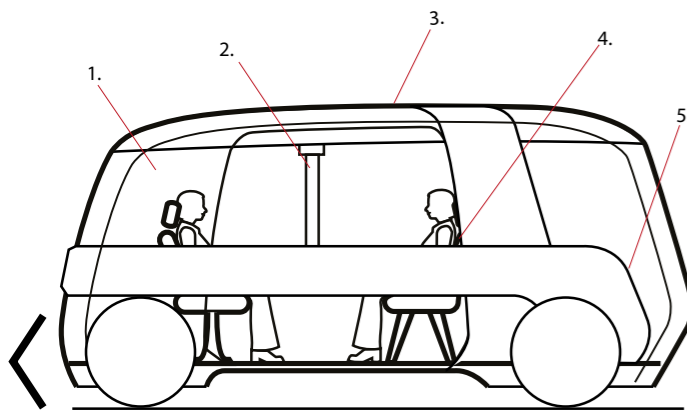
table; a micro kitchen (with fridge, microwave and reusable tableware); pet space and a kids corner for children to play on the move (this latest feature is only usable on fully autonomous roads); and external bike racks and additional storage for longer journeys or trips to the countryside. There is a large screen integrated into a vision panel for shared entertainment as well as the usual induction power points for individual devices.

Navigation is via app control on mobile devices that can be plugged into the in-vehicle entertainment system. All systems are voice and touch controlled but tactile buttons can be added. Navigation information can be seen or heard via individual or car systems and include

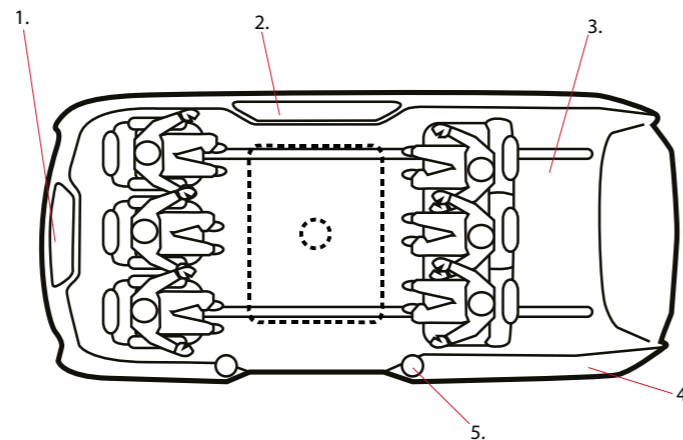
important travel information including estimated time of arrival, potential delays ahead.

Entertainment is provided either via individual mobile devices or the car's audio and visual system, which includes a built in-screen on the side of the vehicle.

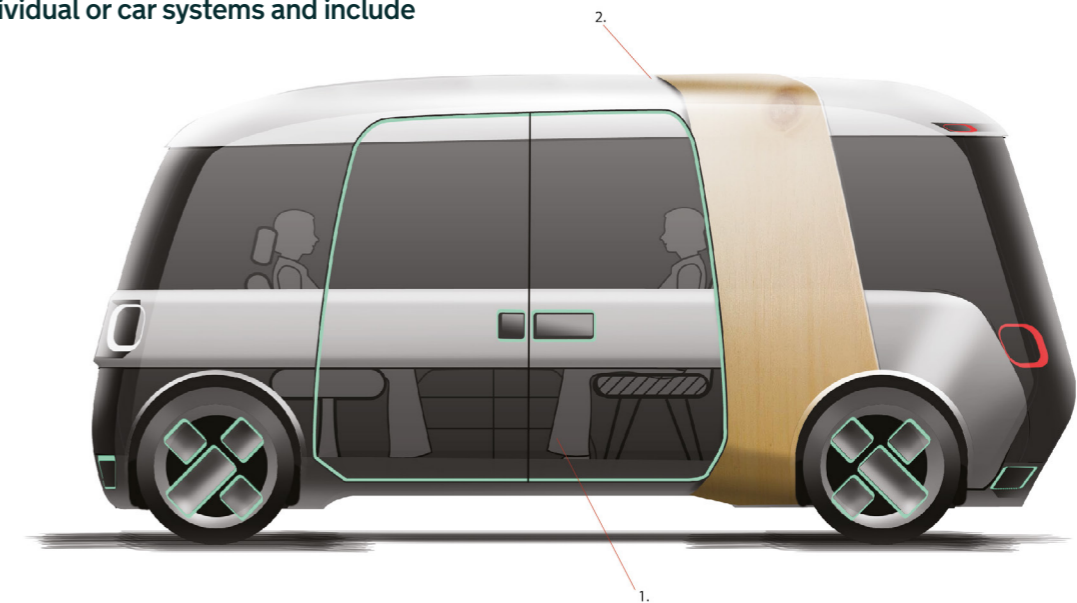
Communications is via mobile devices. Comfort control includes air quality, warmth, light, glare as well as ergonomics via seating including integrated back massage units. The vehicles include an AI concierge feature so that you can ask for advice on anything from shopping and eating to hotels and cultural events.



1. Materials: easy to clean and comfortable
2. Table lowers from ceiling
3. Optional bike rack
4. Reclining & swivelling massage seats
5. Space for luggage, bags, shopping & pram



1. Bonsai Garden
2. Refrigerator control panel, bin tactile buttons, emergency stop
3. Seating can be replaced with baby cot, larger refrigerator or pet seat
4. Temperature and journey control, air conditioning, entertainment,
5. Single side sliding door entry with umbrella holders



1. Single side sliding door entry with umbrella holders
2. Optional bike rack

There is also an emergency 'stop' button that will navigate as safely as possible to a standstill if pushed. The inbuilt entertainment includes educational apps that support games (from eye spy and sign cricket to location-based history games and immersive geography lessons).

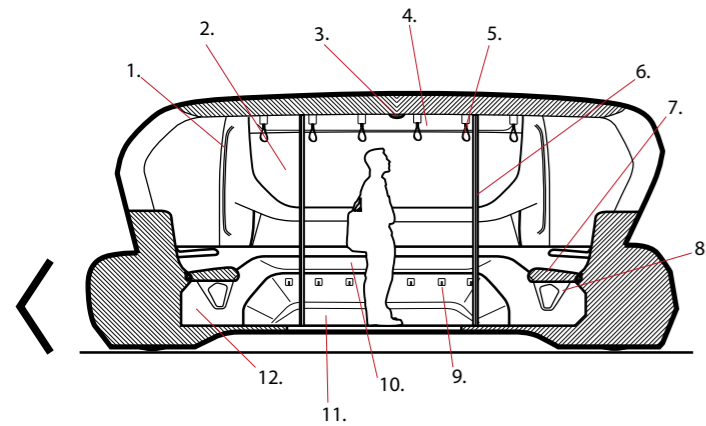
People with driving licences can also install a driving app that allows them to steer and control the vehicle from a Play Station style controller and head up display.

3.2.7
Flexibus
 - an inclusive shuttle
 for communal journeys

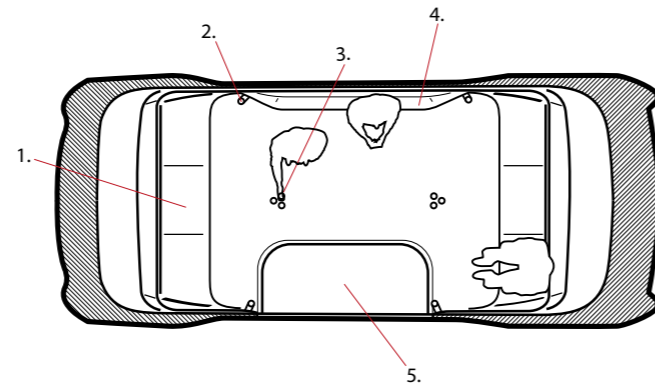
The Flexibus is a community-based shared public vehicle that provides circular routes and street-to-street services within a local area for a range of people including community workers (teachers, health and social care providers), residents with additional needs (parents with children) as well as those in need of local transport solutions. The interior can accommodate between 12 and 18 people depending on layout and purpose. It has a smart just-in-time booking system that allows flexible routing based on demand and big data but can also include permanent local stops such as transport interchanges, hospitals and schools,

so that people can request a ‘just in time’ journey between these locations. You can book from home, on the go and from Flexibus points and touch-terminals in cafés and other local service centres.

Flexibus points show the estimated arrival time for the bus as well as other public transport services. They will also show an alert if the bus is predicted to be full when it arrives at the stop. On board, there are a combination of seats with fold out tables, drink holders and perch points as well as secure space for wheelchairs, buggies, fold up bikes, mobility scooters and parcels. The on-board info system shows the route, stop-off points and estimated arrival time for each stop. This is dynamically updated based on passenger needs and traffic assessment.



- 1. Grab bars
- 2. Secondary information panel
- 3. Vocal information point
- 4. Primary information panel
- 5. Grab handles
- 6. Grab bars
- 7. Bench seating for 3 people
- 8. Luggage spacers / wheelchair supports / buggy supports
- 9. Hooks for bags
- 10. Leaning seats for 5 people
- 11. Recess for bags and luggage
- 12. Counter levered seats



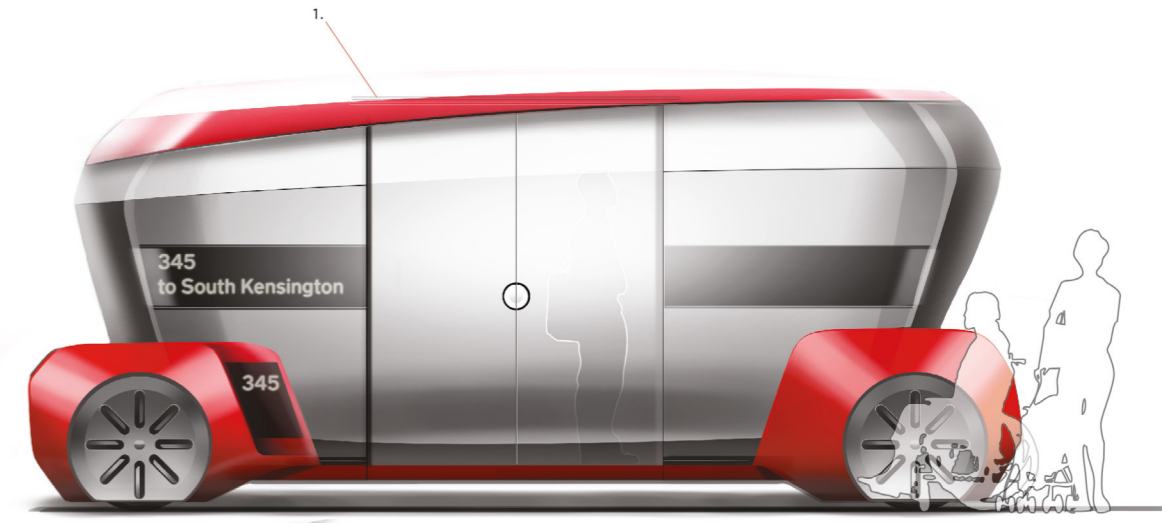
- 1. Bench seating for 3 people
- 2. Grab bars
- 3. Grab bars
- 4. Leaning seats for 5 people
- 5. Entrance and exit area

Flexibuses have many inclusive features including a device-agnostic booking system, a street hail service, pavement level access for wheelchairs and prams, visual and audio displays for navigation (which can be synced with your personal device for simplicity), grab handles and adjustable tint glazing to reduce glare and overheating. The interior space has been designed with comfort and wellbeing in mind to support those who would prefer to sit in peace and watch the world go by.

They are owned by city transport providers, community cooperatives or private organisations and can be adapted for a variety of purposes from local community support, school bus pick up and drop off, or journeys that connect company/ university campuses.

Many Flexibus routes have a shuttle concierge who can help people with additional needs including those with disabilities, heavy shopping, little children, tourists etc. Where a concierge is not available, you can also talk to an AI service rep that can answer local queries and deal with emergencies. Emergency stop and escape instructions are included as standard.

Digital advertising can be integrated into the service to reduce costs to passengers although most people get enough marketing via their personal devices.



- 1. Extendable rain cover

The Flexibuses are charged and maintained in local depots but some authorities have included high voltage induction charging systems at Flexibus stops to increase their range.

Colleges and other organisations in order to provide campus to campus or remote worker support facilities have also adapted Flexibuses. The interior of these vehicles provide for individual and group working as well as remote conference facilities.

3.2.8

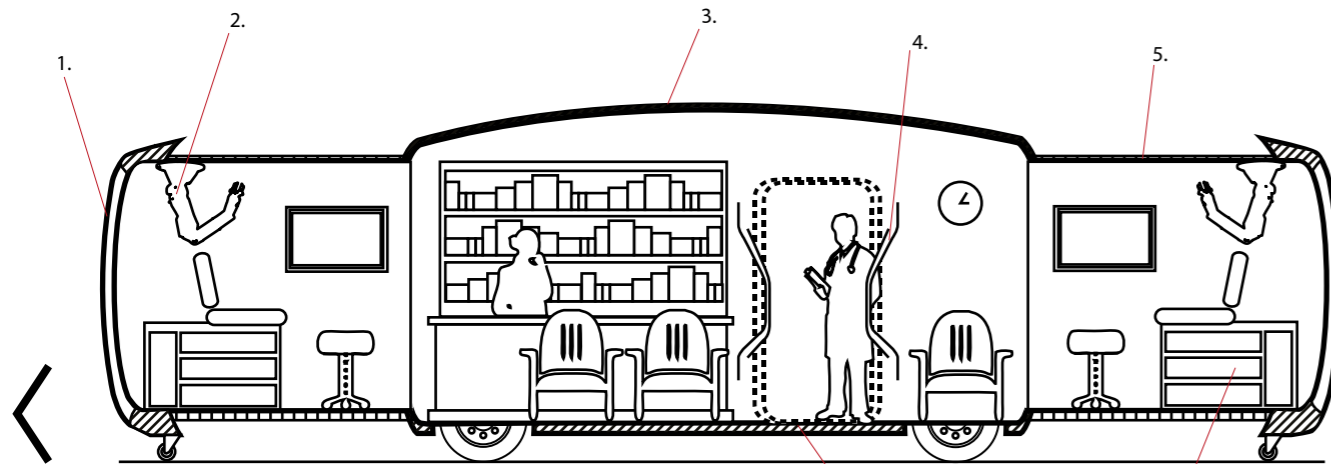
Health2Community

– a mobile health centre that brings care to the heart of a community

Health2Community (H2C) offers an effective environment that allows health trusts to support people in their communities. It provides an adaptable space for a wider range of services and means that people with limited mobility have improved access. The units also provide an integrated approach to social and health care practice bringing together practitioners who can support both mental and physical health and wellbeing. The H2C units have an expandable interior space that allows health, social and community

workers to move in and around the local area. The exterior of the vehicle can be recognised through its NHS branding, is compact while on the move but can expand to provide additional space when it is parked. They often park in schools or parks and can be attached to utilities for water, waste and power rather than relying on internal storage.

The unit navigates autonomously based on a weekly schedule, allowing staff to prepare for the day ahead and alerting patients when it is near. Scheduling the vehicle is part of the overall community health management service but the units can also respond to emergency incidents or other community needs including school visits or health campaigns.



1. Adjustable tint privacy window
2. Robotic assistance arm
3. Transparent roof
4. Grab handles
5. Expanding structure
6. Doctors equipment & supplies
7. Wheelchair accessible



While the H2C service is not a panacea they are beginning to restructure the way that health practitioners work together and interact with the communities that they serve.

This format of vehicle can also be adapted to serve other purposes including market stalls and mobile bicycle repair centres.

3.3

Moving goods around the city

This section looks at how logistics and moving goods around the city will be affected by autonomy. While people movement will still account for the majority of vehicle traffic in a future city, moving goods in and around London will remain critically important in terms of productivity and utility. And, while goods vehicles currently make up less than 10 per cent of traffic, they are responsible for a significant component of London's air and noise pollution as well as road casualties and deaths.

Although we have not specifically spoken with the public about logistics, we believe that autonomous technology will have a significant impact on the way in which products are moved around London; and that these changes will not only improve the efficiency of logistics' organisations but also impact on people's daily lives through changes in the physical environment of the city, employment practice and the infrastructure needed to support material distribution.

Some of these impacts will be positive including reduced vehicle size, fewer vehicles, lower emissions and increased road safety. Others may be negative, banned or highly regulated, including unmanned aerial vehicle (drone) deliveries and the use of pavements for goods movement.



Fig 16: Letters, parcels and packages being delivered in London by bicycle and motorbike couriers as well as in vans and trucks

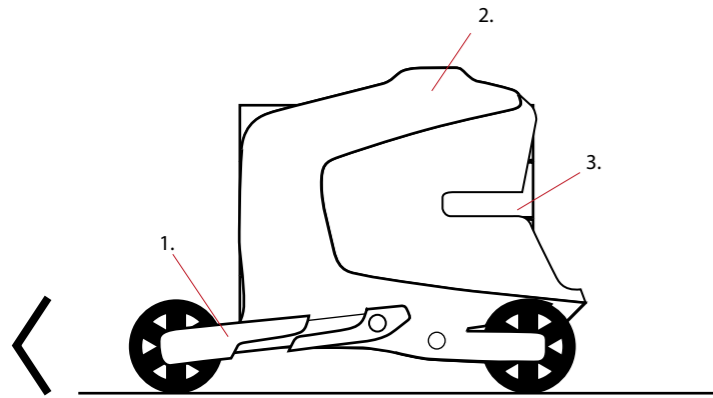
3.3.1
Sharewell Pods

Sharewell uses a network of ‘pods’, ‘Motherships’ and ‘street / apartment lockers’ to help people to send and receive letters, parcels and goods from individuals and organisations. The Sharewell system is similar in scale and intent to the Dabbawala distribution network in India but also allows for local point-to-point deliveries as well as more traditional multi-stop sorting and distribution centres.

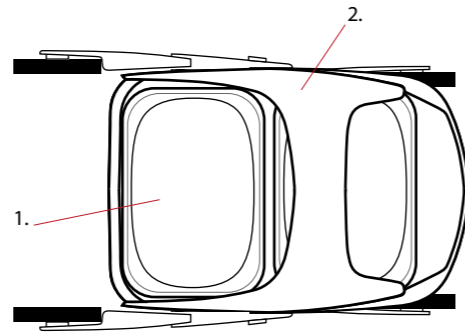
The service encourages local use by providing free or low cost local deliveries outside peak

times. This helps local communities to share everything from books and fresh bread to plants and DIY tools while also helping local shops to compete with global competitors.

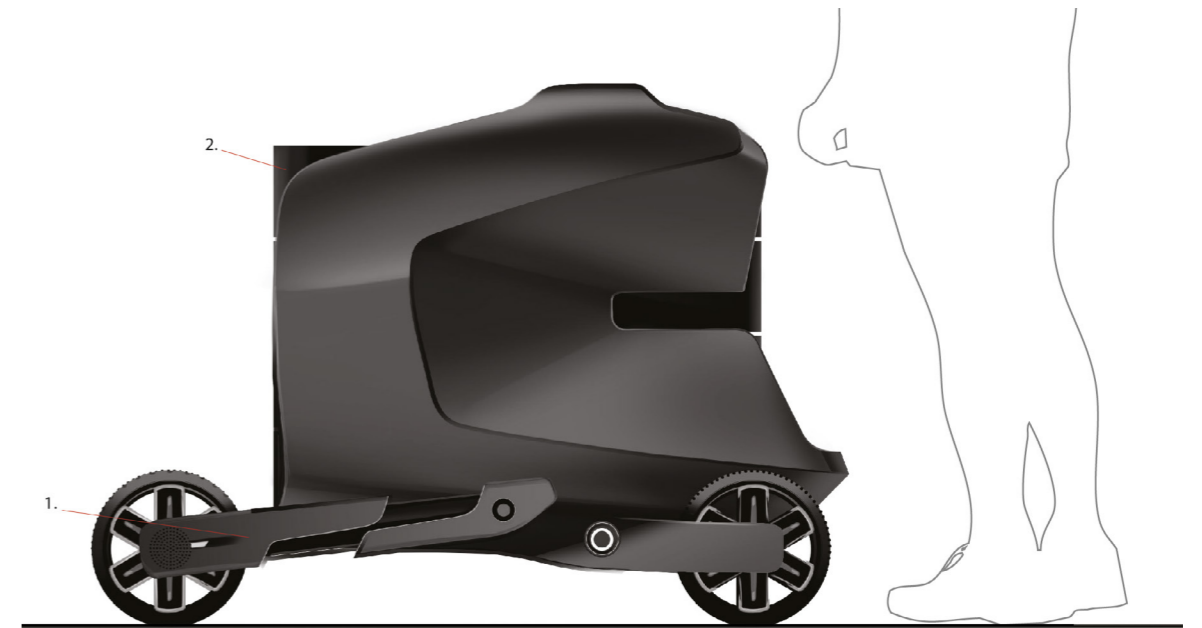
Delivery and collection points include shops, cafés, libraries and health centres as well as storage lockers to create a decentralised parcel management service that fits the needs of a diverse community.



- 1. Extendable arms for stability and curb climbing
- 2. Frame
- 3. Capacity for eight revolving trays



- 1. Trays
- 2. Frame & Sensors



- 1. Motor inside each wheel
- 2. Trays accessible at front of bot

Pods have rotating shelving units based on industry standards that allow individuals or shops to deliver a range of parcels to homes, offices or other collection points within your community. Pods are also used to return unwanted goods or reusable packaging to the supplier.

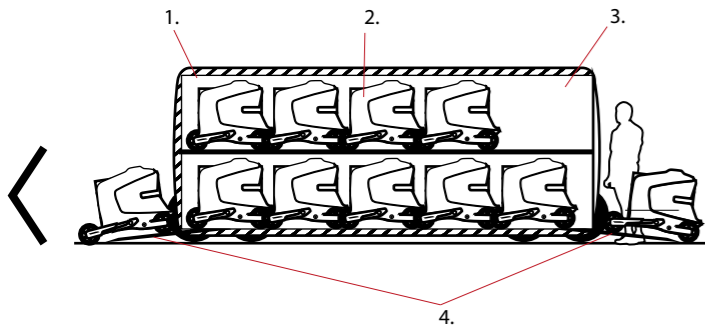
3.3.2 Motherships

Motherships pick up and distribute a herd of pods that are then returned to their local distribution points or taken to a point close to their intended destination. The Motherships have a stacking system that allows pods to be organised internally while on the move and can even support on the move sorting to reduce the footprint and complexity of centralised sorting systems.

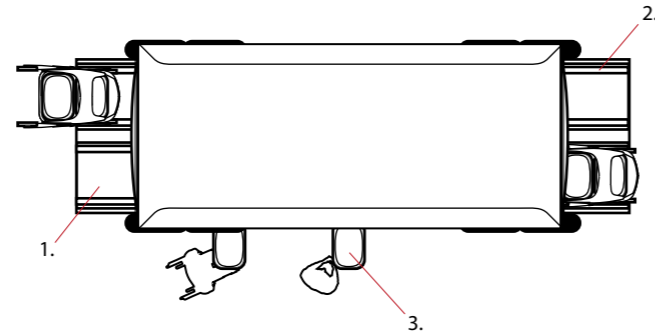
While many homes and offices receive goods directly, there is also a network of shop and street lockers that reduce the chance of missed

deliveries. Simply identify a local street locker or collection point and your parcel will be sent to that location and stored in the correctly sized locker. You can open the locker with your device or send the virtual key to a friend or colleague so they can collect it for you.

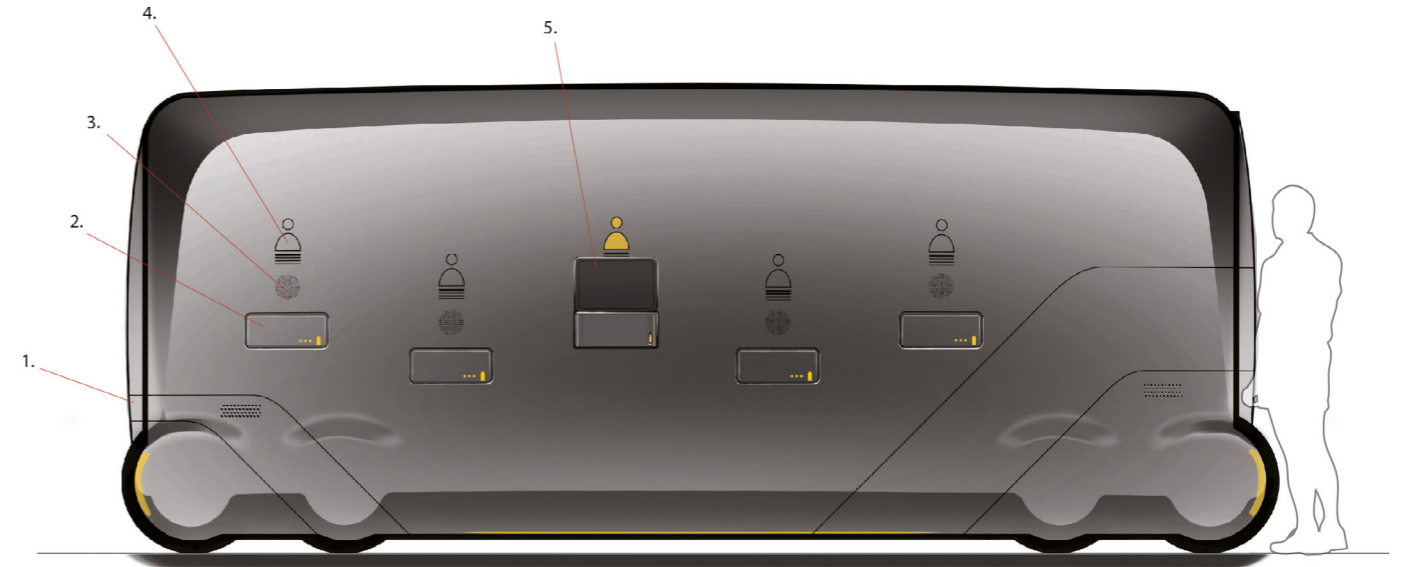
For an additional fee, pods can also deliver to you in person using GPS and smart identification keys. This means that you can pick up your parcel on the go provided that you are in a relatively static location.



1. Vehicle wall
2. Stored delivery pod
3. Vehicle and smart crate storage space
4. Delivery pod entrance and exit area



1. Guided exit ramp for delivery pod
2. Guided entrance ramp for delivery pod
3. Delivery smart crate that extends for greater user access



1. Pod delivery crate insert panel
2. User access to smart crates
3. Speaker
4. User interface
5. Open and extended smart crate

All components of the Sharewell service can support interactive screens, secure locks and smart trust based opening and payment systems to protect integrity. They also have a random network of 'digital sniffers' that prevent or reduce the chance of inappropriate use. Sniffers include a variety of digital trackers, dogs and even trained insects!

Sharewell services will open up a wide array of new opportunities and companies may specialise in bespoke systems to support specific vertical segments such as local food, gardening and fashion.

3.3.3

WhiteVan

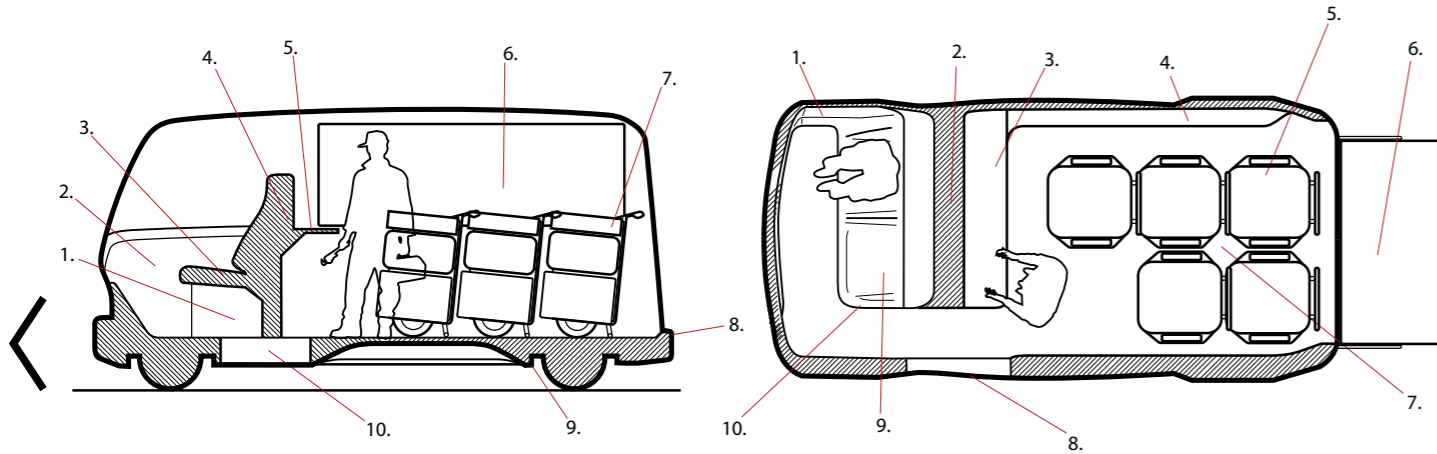
- helping to keep our homes
up to scratch one toolbox at a time

WhiteVan is a tool and material delivery service that uses just-in-time and demand prediction technology to enable the swift delivery of equipment and materials to the plumbers, electricians and builders who maintain and improve our homes.

Craftspeople order equipment just in time and it will be delivered to their clients' homes via a network of responsive automated delivery vehicles that are designed to hold a wide range

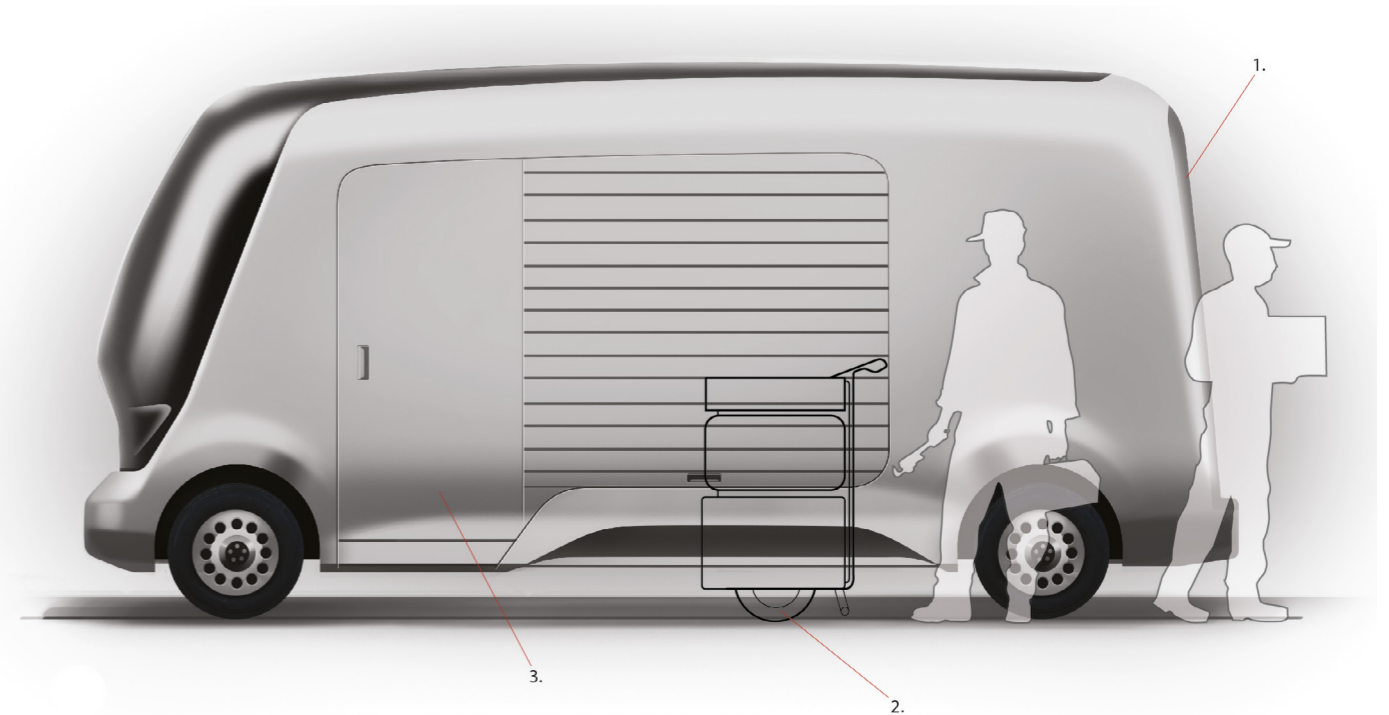
of different equipment and material containers. This means that tradespeople no longer need to retain large stocks of equipment or materials, sit in traffic, own their own tools (some of which they may only use occasionally) or leave someone in the van to avoid a parking ticket.

Tools are used more effectively, can be upgraded more quickly and the service reduces the cost of home maintenance and upgrades as teams waste less time stuck in traffic and can do more projects each day. They can also store their own equipment and tools in shared storage / maintenance centres and get a WhiteVan to pick them up and drop them off at site.



1. Lockable storage
2. Small refrigerator and bin
3. Seating for up to three people
4. Small microwave
5. Workbench
6. Additional tool storage
7. Driverless dollies
8. Tail lift
9. High ground clearance
10. Access for tradesmen

1. Small refrigerator and bin
2. Small microwave
3. Workbench
4. Additional tool storage
5. Driverless dollies
6. Tail lift
7. Dollies bay
8. Access for tradespeople
9. Seating for up to three people
10. Lockable storage (under seat)



1. Tail lift
2. Driverless dollies
3. Access for trades people

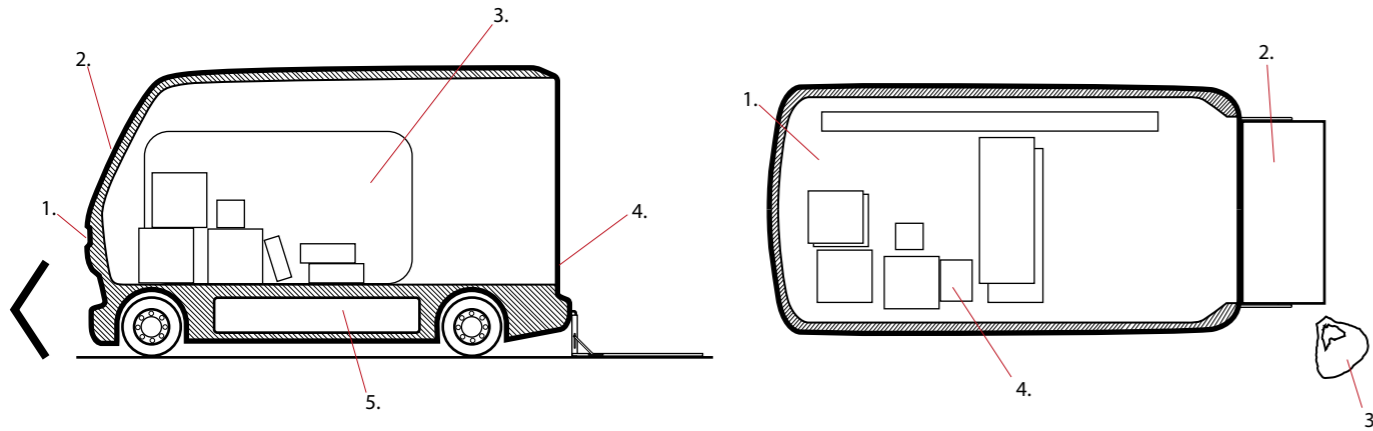
Each WhiteVan has a modular system that can store a variety of digitally locked robust and reusable storage containers. These are loaded onto the van from hire or storage centres. They also have space for a worker who helps with loading and unloading tool-kits and can provide advice to people on new products and services.

3.3.4
BigDeliver

BigDeliver is a delivery service for large items that need additional help to get them into your home or workplace for assembly or installation. People browse catalogues, online services or take public transport to, for example, a furniture store to try out and purchase items. Once they have placed the order they can choose how and when they'd like it to be delivered and what additional services they would like to use. These might include delivery to inside your apartment, installation and testing, assembly and old product / packaging removal.

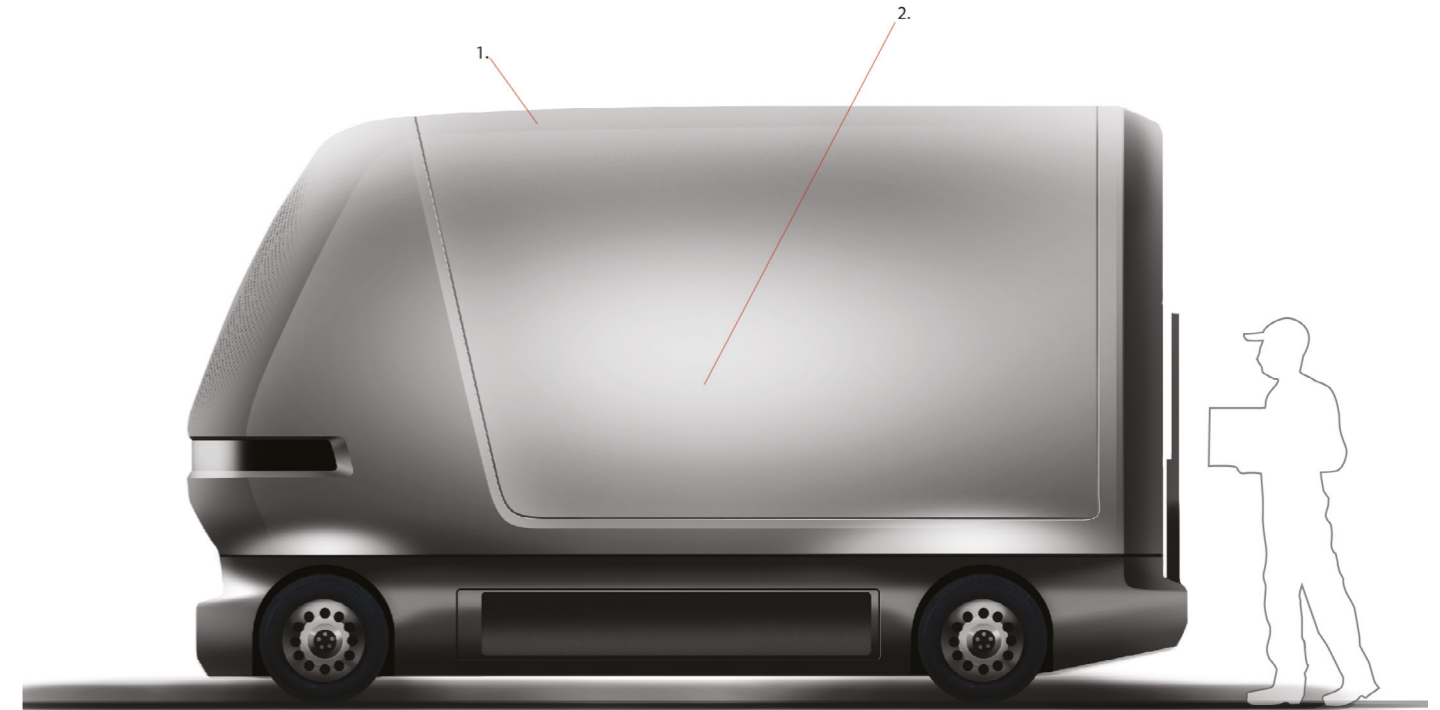
Rather than using the vehicle's driver to do these additional services, just-in-time software organises helpers, who often live in the local area, to meet the vehicle at drop-off points, take the package from the vehicle and then carry out supporting services as required. Where these aren't needed, the customer can pick up the delivery and carry the item into their home on their own or pick it up from a local pick-up point.

Local installers often work in small teams to make their job easier and to improve the work experience. They spend less time commuting or moving between jobs and they can do other jobs if installation work runs dry.



- 1. Primary screen where key information is displayed
- 2. OLED screen on front of vehicle
- 3. Larger interior space for goods
- 4. Lift access
- 5. Lower storage

- 1. Larger interior space for goods
- 2. Lift access
- 3. Local person assisting with delivery
- 4. Goods



- 1. Platooning capabilities
- 2. More compact length

Where the distance between jobs is large or when additional installation kit is needed, the delivery teams make use of last mile Autonomous Vehicles like M-Scoots or City Zips to get to their next job. Many also use exoskeleton supports that make it easier to lift heavy objects and to avoid future back problems.

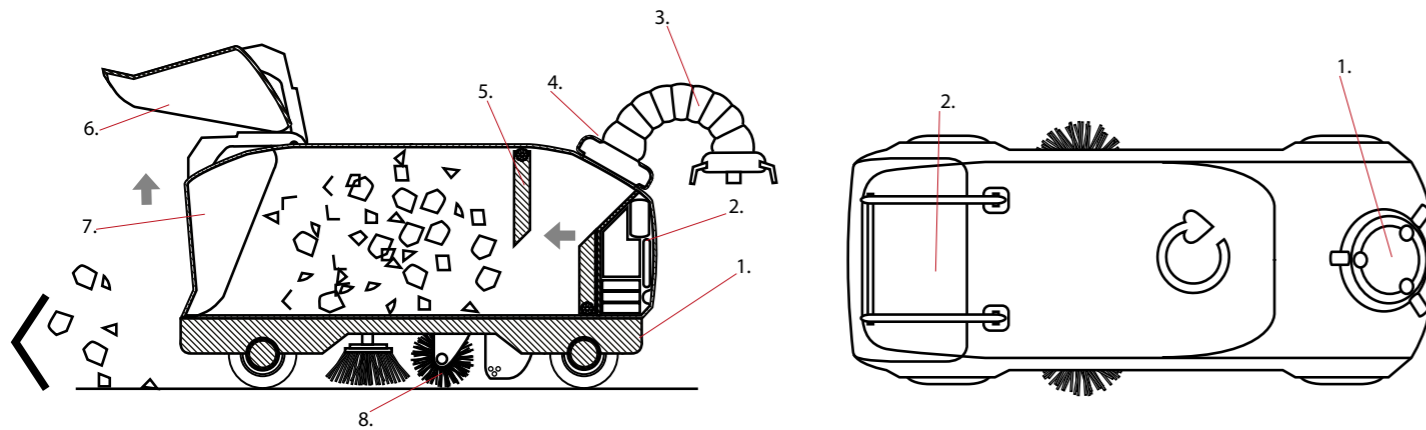
3.3.5 CircularServices

CircularServices is a local authority controlled service that uses autonomous material collectors that pick up household and business surplus materials (previously called waste) from specially designed street-side collectors that facilitate the reduction, reuse and recycling of all organic and inorganic material as part of London's circular economy network.

CircularService vehicles include environmental quality sensors to help local authorities monitor the type of materials being collected as well as outside biodiversity and ecosystem measures. They also include

air and street sweepers to improve street cleanliness and seed dispersers to encourage new growth and biological diversity. Street-side collectors will call to be emptied based on internal sensors and predictive technology. Within the circular service vehicles, an internal compactor compresses excess material into a compact volume and externally it has a quiet and efficient vacuum tube to extract material from the street side collectors.

The circular service vehicles are smaller than current rubbish trucks as they do not need to run on a fixed schedule and can do more frequent journeys.

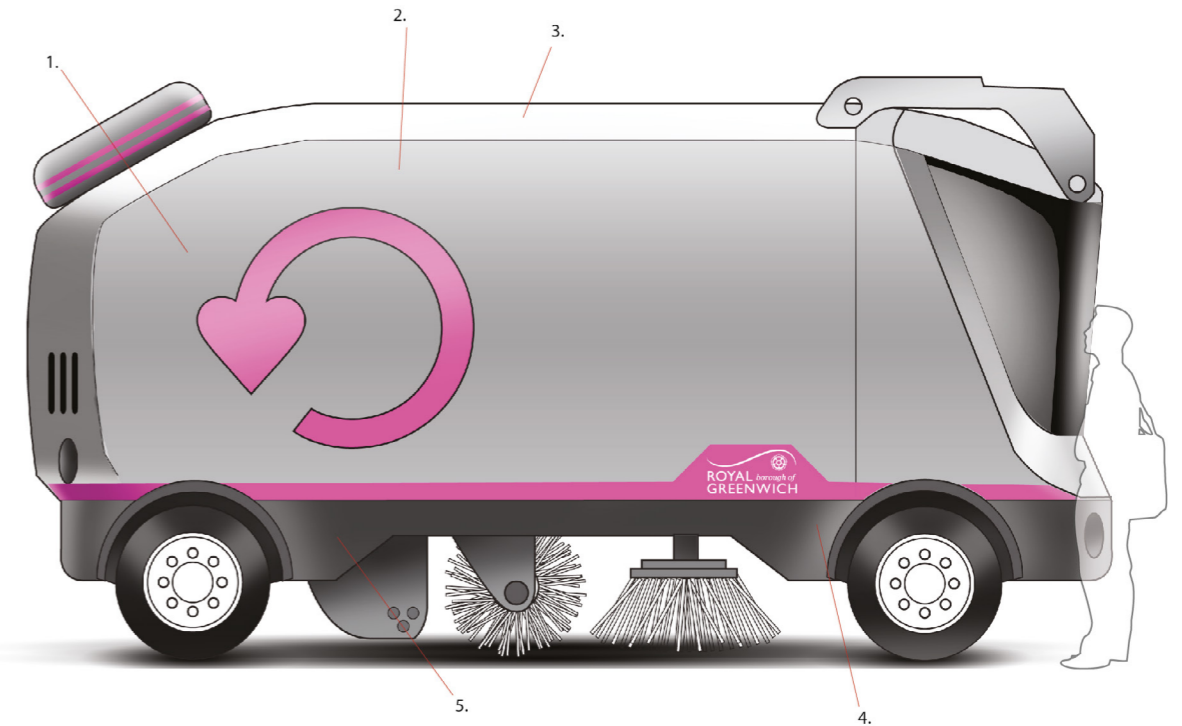


1. Battery chassis
2. Suction motor
3. Hose & nozzle
4. Suction turbine
5. Crusher
6. Door open
7. Door closed
8. Brush

1. Hose and nozzle
2. Door

Externally they are coloured based on the material that they are transporting and many include playful messages that encourage everyone to do their bit to keep the community clean and tidy.

The circle navigates between street collection points based on demand and can collect outside of peak traffic. Householders can also get alerts so they know when the next collection will be so that they can make sure they have taken out any recycling bags.



1. Noise dampening exterior
2. Large storage capacity
3. Accessible roof surface
4. Battery chassis rear
5. Battery chassis front

The circle collector also has sensors for environmental quality, cleans the street as it moves between street material pick-up points and can disperse wildflower seeds into street side green spaces. It can also collect materials from designated street bins.

The circle uses standard indicators and lights to communicate with other vehicles and people and can be stopped in an emergency by remote control or an external emergency stop button that is monitored by remote staff.

3.3.6

Other bots and drones

While the majority of goods delivery and material collection can be carried out using service vehicles noted above, we have also identified special needs and extreme use cases that may make use of other automated delivery systems.

These include air-based drones that may be used for high speed delivery or surveillance activities over designated areas; shopper bots that can move autonomously next to people with limited mobility to help them to carry heavy items; and even bin-bots that can carry and deposit unused materials to circular service pick-up points.

All the services described have a number of social, business model and technical challenges that require additional stakeholder engagement and design research.



Fig 17: A range of potential future drones and bots developed by researchers at the RCA. Clockwise from top left: a dog-walking bot; a noise absorption vehicle; a pavement-based package delivery bot and a 'bee-bot' designed to increase plant pollination speeds



Fig 18: A future street where people, bots and drones live in cybernetic harmony

4.0

The Experience of Mobility

While a healthy city must be designed to support and encourage active and inclusive travel as a priority, autonomous vehicles will play a significant role in the future experience of mobility.



4.1

Experience of mobility

Twenty years ago, experts at the RCA reconceptualised the ambition of ‘a car for all’ as mobility for all (Coleman and Harrow 1997). The implications of such a change are profound: the potential transformation from personally owned vehicles to shared services is changing industry (Bardhi and Eckhardt 2012), and technology giants internationally have had to consider new forms of mobility and business models. Business models are becoming service-dominant, moving from delivery of products and stand-alone services to the provisioning of solution-oriented, integrated services to customers. Products become part of the delivery channel of services, not the focal point themselves. The emphasis shifts from the value of the individual product or service to the value of the use of the product or service in an integrated context – ‘value-in-use’. We are witnessing a concomitant shift in the perception and design of vehicles; first as products, then as elements of a service, and now as an aspect of the complete mobility experience. This mobility experience is determined by several factors: the availability and quality of transport choices, the ease with which we can access a service, the cost and time associated with using the service, and the quality of the personal and social experience at every touch-point and interaction from before the point of departure onwards (Le Vine and Polak 2017; Diels et al. 2017; Haboucha, Ishaq and Shiftan 2017).

This transformation has been driven in part by the adoption of technologies and applications such as artificial intelligence, open data, autonomous navigation, high speed telephony

and integrated personal devices. New concepts of mobility services have been imagined and tested, such as vehicle-sharing, high-speed urban commuting and robotic delivery. Each of these innovations interacts with changing attitudes and expectations on the part of users. For them, the adoption of any particular mode of transport depends on affordability, driving experience, style, personalization, comfort, privacy, utility (Mitchell et al. 2010), but, in addition, lying behind car ownership has for decades been the aspiration to personal autonomy (Kent 2014) and the desire for mastery, self-esteem, and prestige (Ellaway et al. 2003). There is particular controversy over the future of shared transport – to what extent will people forsake their private cars (Stayton, Cefkin and Zhang 2017)? Or will they be forced to (Litman 2018)? Public sentiment is still unclear: while sharing is a longstanding form of human exchange, the market currently proposed is one where, to an unprecedented degree, it is strangers who will exchange goods and services (Schor and Fitzmaurice 2015). A recent study co-located with GATEway found that autonomous vehicle technology was the aspect of the service which potential customers were most excited about, whereas respondents were hesitant about sharing a journey with strangers (Merge Greenwich 2018). While some observers are convinced of a profound shift to sharing in society and the economy (Botsman and Rogers 2010; Belk 2014), others point to the conservatism of consumers (Haboucha, Ishaq & Shiftan 2017; Bansal, Kockelman & Singh 2016). Policy makers also need to acknowledge the constraints of regulatory systems and consider how to optimise the effectiveness of policy interventions for desirable outcomes (Datson 2016).

4.2 Ownership

Ownership is a significant factor when determining how a vehicle is designed and supported. Personally owned vehicles may be more bespoke and adaptable, when shared, public and civic vehicles need to be more inclusive, robust and easier to maintain.

During our ‘driverless shuttle’ research we found changing attitudes towards vehicle ownership. While two-thirds of our participants would mainly choose public transport, almost 20% would prefer to spend more on a privately hired vehicle and the remaining 15% would like to own a vehicle outright. However, many of these would be happy to share or rent it to others rather than having exclusive use. Overall it points towards a significant reduction in the number of personally owned vehicles on the road, a desire for greater access to shared private vehicles and a positive preference towards public transport. The quality and aesthetics of different vehicles will depend on the business models associated with ownership and use.

While the wealthy can afford more private, delightful finishes and options, other industries, particularly mobile and internet-based organisations have shown that quality materials and features can be made available for many more people provided that services are used intensively and payment plans amortise costs over time.

If, for example, a shared vehicle is used more intensively than current vehicles by ensuring that it can be moved to meet demand, then its finishes and features can meet higher quality thresholds while also being a cost effective and profitable solution. As Gustavo Petro says, “A developed country is not a place where the poor have cars. It’s where the rich use public transportation” and for the rich to use public transport, the service has to provide a better quality of experience than the alternatives.

A total of 48 people completed the workshop activities including 16 women and 32 men. Half held a current driving license, six people had additional needs, eight were technology enthusiasts and six were classed as professional stakeholders. 17 were under 35, 22 were between 35 and 54, and 9 were over 55.

What vehicle would you use in London?
Views of participants during driverless shuttle trials:

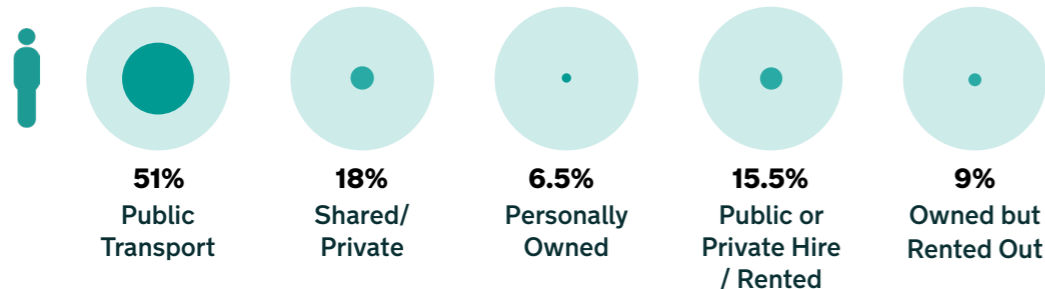
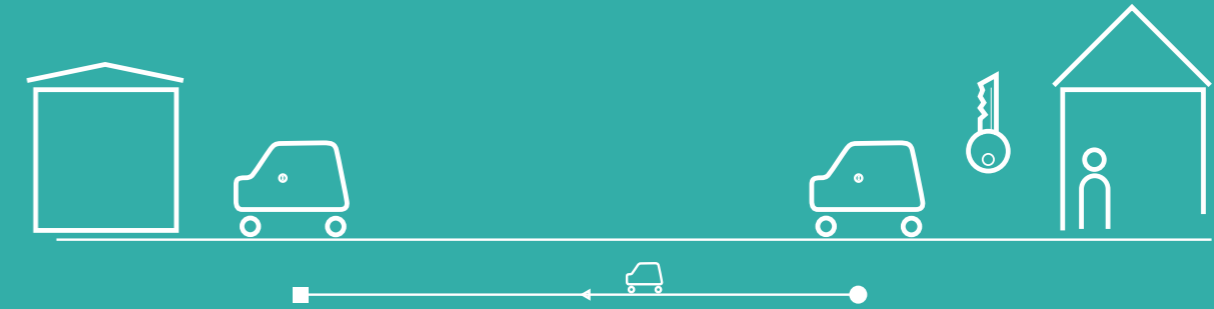


Fig 19: Table showing preferred future ownership model during driverless shuttle research (see 7.4.3)

Ownership Model

Today



2035



Fig 20: Future Ownership models provide mobility without full ownership. Vehicles, based on need, can be summoned using an app, transport you to your destination and then go off to pick up their next passenger. These shared vehicles may be owned by individuals, public co-operatives, local authorities or private organisations

4.3

Exterior features

- body, communication, safety

The exterior features of an AV will serve similar functions to those of current vehicles but will need to adapt to include all of the active sensors needed by autonomous vehicles as well as the indicators that tell others what it is doing and what it is intending to do. Additionally, future vehicle exteriors will change based on improved accessibility, material technologies, changes in safety requirements and changes in shape and form, based on the needs of passengers as well as those that maintain and service the vehicles.

Sensors may initially be relatively prominent features on vehicles (as seen on the Google Car) but it is likely that these will become invisible as technology advances.

More importantly, the indicators that driverless vehicles will need to communicate intention may well go beyond those currently seen in driven vehicles. These active communicators may simulate the intentions that we often see in drivers today - 'I have seen you', 'Watch out' or 'Thanks for slowing down'. Communicators on the rear may tell approaching vehicles to 'slow down', 'there is an accident ahead', 'it's not safe to overtake me'; while communicators on the side may welcome expected passengers by displaying a name or a greeting message. A team of ex RCA graduates have been looking at humanising autonomy by considering three interlinked issues - measuring human intent, classifying body language and improving situational awareness. But the interfaces that are developed will need to have universal appeal and understanding. They may be variations of existing vehicle and road signage but in the future they may extend

to include emoticons and other human to human symbols as well as sounds and vibrations.

Doors and access to a driverless vehicle may also change significantly as vehicles become more inclusive and integrate with other services. Conventional locks will be replaced by device controlled soft-keys and doors will have motor assist for easy opening. With more flexible interior arrangements, passengers will be able to access the vehicle from the pavement side or from the front of the vehicle, avoiding some of the danger from stepping out into moving traffic.

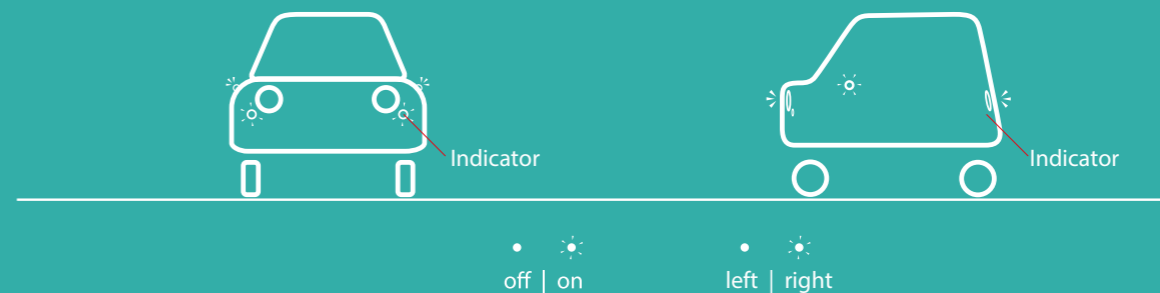
Vehicles will also have features that help people with additional needs get in and out more easily. Ramps or crouching technology will help disabled people or those with prams or shopping get into the vehicle. Wider sliding doors may improve access while more grab handles and higher roof lines will make it easier for older people to get in or out.

Vehicles may also interact with other autonomous services to improve the efficiency and cleanliness of urban travel. Boot spaces may be provided with hatches that allow smaller delivery pods or service providers to pick up or drop off shopping or post while the owner is away. On public or shared transport, bins may include extraction hatches that allow contents to be emptied while they are parked, without needing to access the interior directly.

Finally, new materials may create softer or more technologically advanced exteriors. Advanced composites will replace metal panel work, digital screens may be incorporated into the glass housing and photovoltaics may be integrated into vehicle roofs to gather energy during the day.

Exterior communication

Today



2035

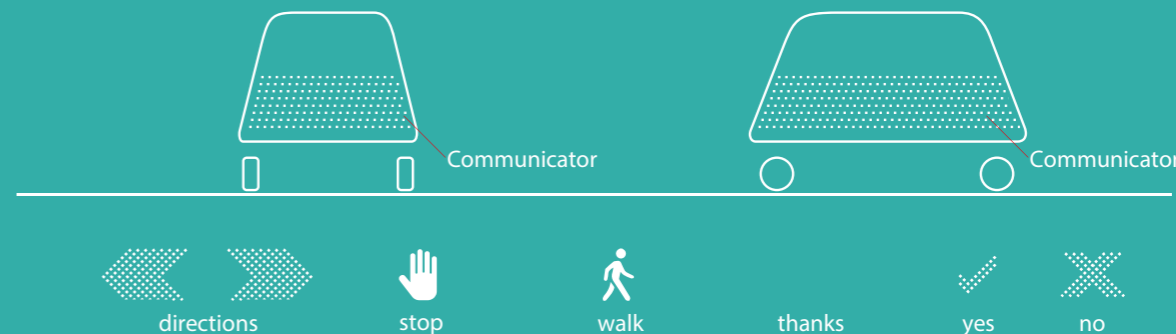


Fig 21: Exterior vehicle communication may move from indicators to communicators, using a range of symbols to communicate between the autonomous vehicle and its fellow road users including pedestrians, cyclists and other drivers

4.4

Interior features

- accessibility, seating, visibility

The interiors of Autonomous Vehicles will transform from spaces focused on driving to environments that attend to the needs of their occupants.

Seats will not necessarily face the direction of travel, although many people still express a preference to see where they are going. As road safety improves, people may become more interested in the social quality of the interior rather than the views ahead, although it's likely that manufacturers will continue to provide forward facing seats or design interior furniture so it can be adjusted to support multiple seating arrangements.

Additional space will be available for those who need it, from flip up chairs that allow people with wheelchairs to share space with other people on an equal footing to space for folded prams or luggage which previously might have been stored in the boot – although these need to be secured.

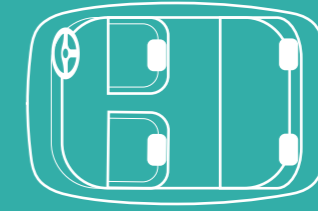
As steering wheels and dashboards disappear, it's likely that the dash surface will become a screen or in shared vehicles a tablet holder or a 'desk' top.

Accessories will depend on occupant needs with popular requests including higher interiors, better grab handles, armrests, cup holders, fold down tables and charging points.

In public vehicles more attention will be given to maintaining a clean environment and information services. In more expensive personal or private hire vehicles we will see high quality entertainment or gaming systems or better facilities for eating or drinking on your journey.

Interiors

Today



2035

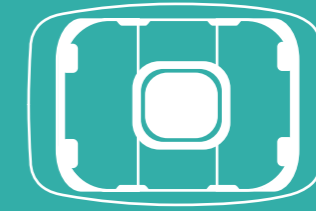
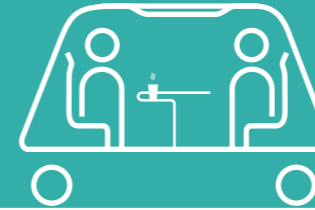


Fig 22: Interiors may change from spaces designed to support driving and individual comfort to those designed for easy access, social interaction and accessible storage

4.5

Interface features

- controls, information, trust

This section looks at the interfaces that people will use to interact with and in driverless vehicles.

These interfaces include devices for predicting and informing passengers about routes, way-points and destinations; information passengers may want or need about the vehicle and its surroundings; communication systems that help them control the autonomous vehicle and communicate with friends or colleagues while on board; entertainment systems that help to create a playful, personal or communal journey; safety and security systems that put safety first while ensuring that people do not feel under surveillance and environmental controls that help to improve ride and comfort while using the latest technology to create scenes and environments that suit the needs and wishes of passengers, young or old.

They also need to deal with the unexpected:

What will a vehicle do if a sensor is vandalised or broken en route?

How will sensors, indicators and communicators manage inclement weather?

How will the service support people who have learning difficulties or physical restrictions? Will it speak slowly, drive more cautiously, give people more time to adjust and settle down?

How will it sense who is in the vehicle and what preferences they might have?

What will it do if it does not recognise all of the people inside the vehicle? Does it need to know this information in order to operate?

What happens if a person walks out in front of it?

How will it warn or avoid people in its path?

How will it be made aware of local changes in road condition, routes or top speed?

Can it signal a pedestrian or cyclist that it has seen them and knows that they are there?

What will it do if the vehicle breaks down or components begin to show signs of wear?

How will it know whether it is in a rush or not?

4.5.1

Navigation

– predicting and informing

Vehicles need to navigate safely in all conditions and, as a minimum, follow the highway code without fault. They also need to deal with unpredictable events and emergencies just as drivers currently do. While they do not ‘tire’ or ‘lose concentration’ current autonomous vehicles do not have the range of senses and experiences to draw on as people, and, unless they are programmed with this information or have additional sensors, there will be many blind spots in their behaviours. They may also be programmed with different motivations, from maximising profit to avoiding areas that are potentially dangerous.

From a passenger perspective, we expect to be able to flag down a vehicle that is free; get into it with ease; bring guests with us if we’d like; settle into a space that is comfortable and potentially set up the space with my or our preferences; confirm where we are going including stop off points en-route; get a sense of the route and the estimated time; along with any potential disruptions on the way; and finally travel with a sense of security and wellbeing.

We expect the vehicle to move as swiftly as possible given the conditions and our own preferences; negotiate turns; roadworks; other vehicles, cyclists and pedestrians without causing distress to them or to us; stop and start smoothly at lights and zebra crossings; we expect to move around safely in the vehicle if allowed; drink a warm drink without spilling it; listen to music or other entertainment; change directions or stop for a break if we

want to; avoid an accident ahead; stop if asked to by the police; not stop if flagged down by someone without authority; park safely in a place that is legal ... the conditions for our wellbeing on journeys are extensive!

So, the navigation systems that we need to develop are more than sensors that can see the route ahead. They need to see and listen to the world around them (in front, behind and to the sides) in detail, see conditions along the route they are travelling, understand our changing needs and desires, communicate with us to confirm their understanding and confirm their intentions if they need to change the behaviour of the vehicle for some reason.

4.5.2

Information

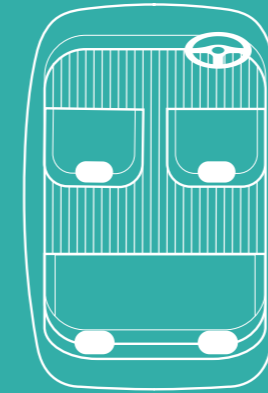
– what matters to me

Many passengers want to know more than where they are on the journey and the conditions around them. In private vehicles they want to know whether their car needs power or needs to be maintained; they want to know what to do in a variety of emergency situations; how to use features that help them to make the most of their journey; how to override systems and features that they don’t want or need. They may also want the vehicle to provide them with additional information about the world around them; where to go; where to avoid; what’s happening around them.

Some of this information may need to be displayed using the vehicle’s own systems while some may be better displayed on a personal mobile device.

Interfaces - navigation and information

Today



direction



location

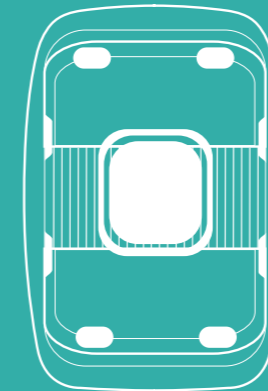


time



speed

2035



direction



location



time



speed



user info



time to destination



surroundings info



pedestrian warning!

Fig 23: Navigational and information systems need to include a sense of the surroundings including pedestrians and cyclists. While passengers want less control over the route and speed, they want to know where they are, when they’ll arrive and expect private vehicle’s to understand their preferred ride ‘style’. Navigational Interfaces will also be available on a range of screens from mobile devices and head up displays to physical buttons with built in screens

4.5.3

Communication

– assisted communication
for mobile environments

Just as today, we will use mobile devices that integrate into vehicle systems to communicate with people outside the vehicle but advanced artificial intelligence will also allow us to communicate directly with the vehicle using our voice and other communication languages such as sign language or gesture control. Vehicles may also respond to passive signals from occupants, such as heart rate or sleep patterns.

A test of the competence of the AI systems that control our vehicles may include their ability to follow the instructions of a driving examiner or the signals from a road traffic controller but the key will be its ability to communicate with a variety of people from 8 to 80 through a range of media interfaces.

4.5.4

Entertainment

– personal and communal play

The future of play and entertainment will be as bound up with the interior experience of autonomous vehicles as it is with home or traditional entertainment environments. While public transport will still assume that people will play or be entertained using personal devices, private vehicles will offer opportunities for solo or group immersive experiences including surround sound and vision as well as 3D gaming platforms. There may even be vehicles that are specifically designed to support some sort of immersive gaming, education or business-related experience.

Interfaces - communication and entertainment

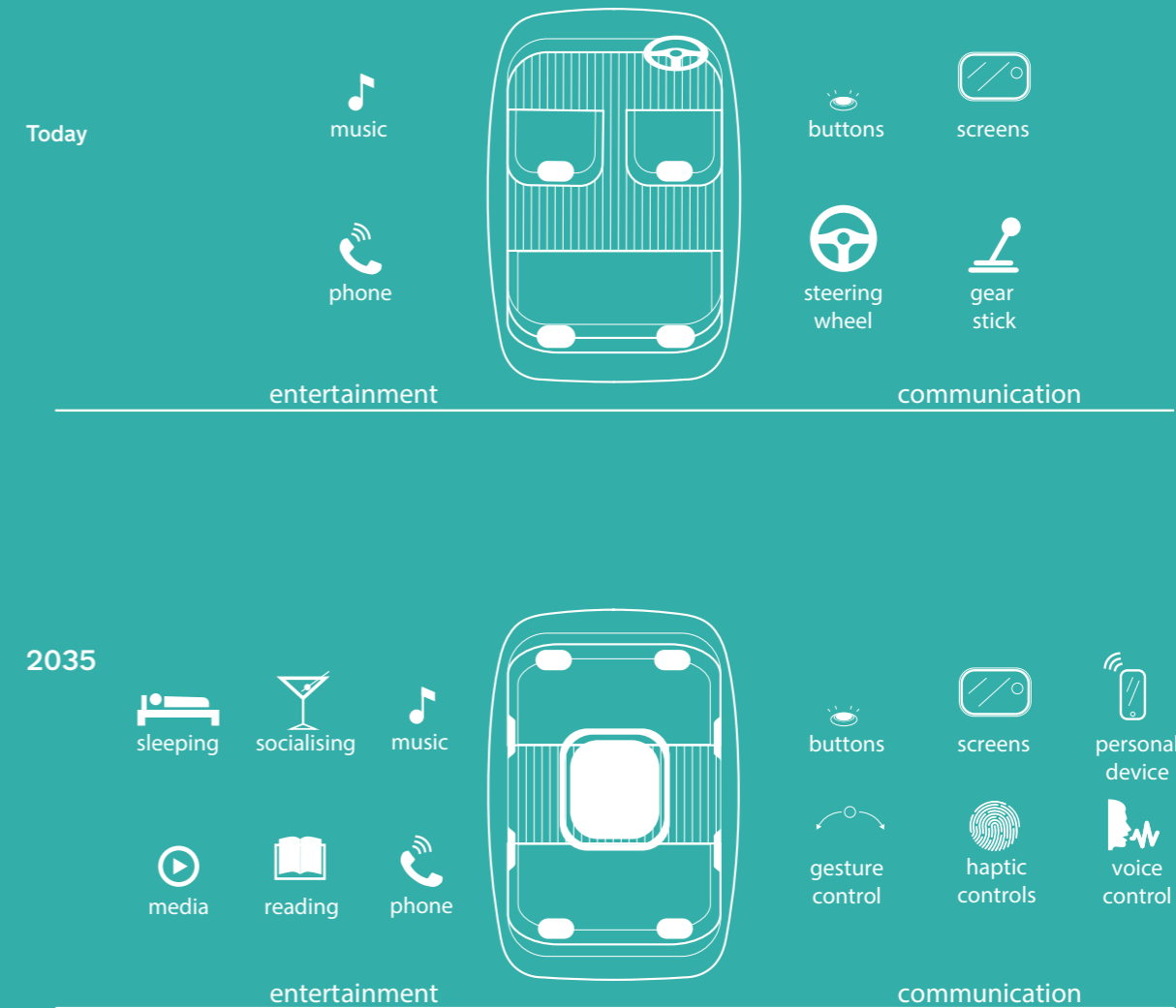


Fig 24: People will want to rest, read, watch a movie or listen to music, drink or eat, get ready on the go, socialise, play with the family, communicate via phone, work or de-stress. As the role of the driver fades, the information, communication and entertainment services within vehicles will become as varied and personalised as those found in homes and workplaces

4.5.5

Safety and security features

– safety first, follow me, follow you

Safety and security systems form the foundation of successful driverless vehicle acceptance but also act as potential fault lines for mass adoption. It won't take many failures of technology or 'big brother' tracking software to make autonomy unpopular.

As a minimum, autonomous vehicles will have a valid and up-to-date driving licence and MOT. They will avoid collisions, negotiate rights of way with other people and vehicles including pedestrians and cyclists, and their services and intent will be transparent and understandable for the general public, controlling the distance and speed they can travel without passengers and dealing with hacking and malware attacks without interruption. A crashed phone is far less of a worry than a crashed vehicle.

They should also be able to support child safety, parental controls and manage personal and data privacy. If they can be controlled remotely, the remote control must be agreed to by passengers except in an emergency. In extreme situations driverless cars must be 'terrorist proof' and be controlled by the appropriate security services so that police can stop them and ambulances or fire-engines can drive past without incident.

Software and interfaces, both internally and externally, should communicate intent in a simple and accessible language.

4.5.6

Environmental control

– ride, comfort, scenes, environments

People will be able to adjust ride quality and the physical environment within the vehicle to suit their mood and temperament as well as meet their practical needs.

Ride quality might range from passive to assertive, but aggressive driving will be off-limits in urban environments and all driving standards will comply with local driving codes with the opportunity to create more granular and time-based control depending on who is in the vehicle and the local conditions. For example, a vehicle with older passengers might have reduced acceleration and take corners more slowly, or vehicles might automatically slow down when passing close to schools, hospitals, cyclists or road users with additional needs.

The physical environment will not only adjust temperature and light but also furniture ergonomics, spatial arrangements and the scene in which you are sitting. These physical and virtual reality environments will have the capacity to place your vehicle within in a virtual forest setting, for example, or connect you more intimately with the environments that you are passing through.

Safety

Today



2035

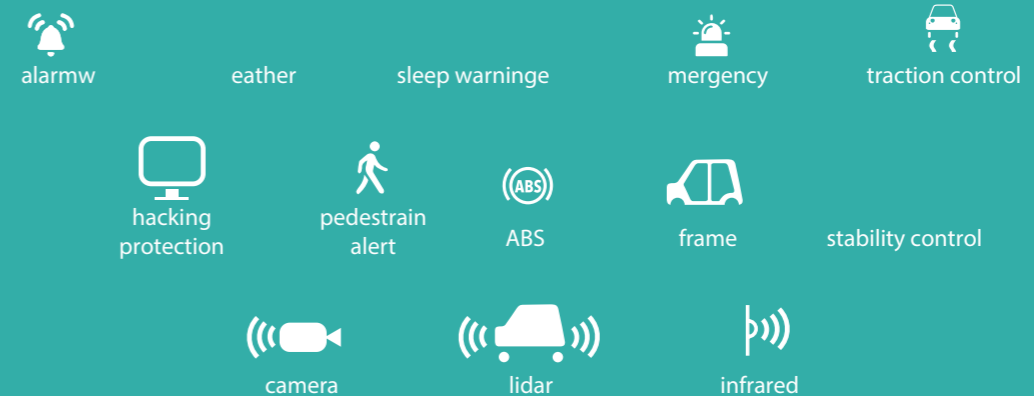


Fig 25: Safety and security systems form the foundation of future autonomous vehicles. Apart from avoiding accidents, they need to ensure that passengers are not in danger (or potentially causing danger to others), giving them the right to override on-board navigation and press an emergency stop button while also protecting its systems from hacking and other malevolent attacks

5.0 Environment and Infrastructure

In this chapter we imagine how driverless technologies can help to create a healthy, vibrant and environmentally friendly city that is inclusive and encourages human interaction that supports new forms of community activity and work.

5.1 Infrastructure and Environment

The driverless car – whether privately owned, shared, or hired short-term like a taxi – is part of a series of wider systems that are not confined to the physical: they include the visible and invisible networks in which people and communities live. They are constantly evolving, as new organisational structures, technology-enabled objects and institutions interact. This infrastructure is not so much an inert framework as an operating system that makes certain things possible and other things impossible (Easterling 2014). Much of it is dictated by entities far away from the places affected. In transport and mobility, Uber is currently an obvious example, its very name suggesting the autarchic nature of its operation, based in California, changing systems of mobility on the other side of the globe. Autonomous mobility provides a new element of potential control and complexity over our urban lives, one that is expected to fundamentally change the relationship we have with our cities and suburbs, and with our homes, work and play. Autonomous vehicles will revolutionize transportation, and dramatically change the urban form (Meyer, Becker, Bösch and Axhausen 2017). The percentage of the world's population living in urban areas is projected to increase from 54% in 2015 to 60% in 2030 and to 66% by 2050 (WHO 2016). Each city is a complex system including social capital, an economic development strategy, spatial organization and planning, the technological systems infrastructure and the services and content it delivers, and the principal actors involved in the commissioning, provisioning, deployment,

and consumption of services (de Leon 2011). And each of these elements impacts on innovation and policy. Autonomous vehicles are enmeshed in these systems, making it hard to predict consequences for the future.

The urban mobility systems we have now are not working well, nor working equitably. A 2013 Technology Strategy Board report suggested that, while transport is clearly essential in every aspect of our daily lives, the impact of the growing demand for transport is reaching saturation, with impacts to the environment, health, economy and energy use. In the UK, road traffic congestion is expected to increase by 25% to 2022, with transport contributing up to 30% of carbon emissions, of which 40% is from cars (Kell, Tucker, Hart and Everett 2013). The Eddington Transport Study (2006) estimated the cost of road congestion to be £7-8bn of GDP per annum. The use of land for parking represses other land uses, eventually leading to reduced density of economic activity. Downtown Buffalo, New York, allocates half of its land to parking, Downtown Albuquerque, New Mexico, more than half, while in downtown Topeka, Kansas, the share of land dedicated to non-parking uses is so small that there seems little reason to travel there and park (various sources cited by Zakharenko 2016). Making cars is as environmentally damaging as driving them. Exhaust-pipe emissions make up about half of a car's carbon footprint; one-third lies in the manufacture and maintenance of the vehicle, with the remaining one-sixth in the supply chain of the fuel. The emissions from the manufacture of a luxury car scrapped after 100,000 miles may be up to four times higher than the tailpipe emissions of a small saloon (Berners-Lee 2010.).

One contentious question is whether autonomous vehicles will decrease or increase the number of vehicles on the road. At first glance, any shift away from privately owned vehicles that are idle ninety percent of the time seems certain to decrease overall numbers. Modelling by Fagnant and Kockelman (2014) suggests that a system of shared autonomous vehicles might save a community ten times the number of cars they would need for self-owned personal-vehicle travel, though it would incur about 11% more overall travel: the emissions savings would be sizeable. Thomopoulos and Givoni (2015) however concluded that autonomous transport risks a future mobility that exacerbates, rather than relieves, current deficiencies of our mobility systems, including its high carbon and high cost characteristics. Only a change where public and sharing is seen as superior to private and individual transport could make the autonomous car a benefit. Similarly a report from UC Davis and ITDP found that vehicle electrification and automation may produce potentially important benefits, but without a corresponding shift toward shared mobility and greater use of transit and active transport, these two changes could significantly increase congestion and urban sprawl, while also increasing the likelihood of missing climate change targets (Fulton, Mason and Meroux 2017). Under these perspectives, it is not autonomy itself that will make a difference to sustainability, but sharing.

When taking a systems view of mobility, it is essential to avoid generalisations that overlook difference. Massey (1993) was among the first to point out how the spatial and time compression widely claimed for urban mobility is not the same for everyone

regardless of wealth, gender or other factors. She highlighted how the extent to which we can move between countries, walk about the streets at night, take public transport, or venture out of hotels in foreign cities, is not influenced simply by universal changes such as the flow of capital or the availability of technology. Rose in the same volume pointed out how 'women know that spaces are not necessarily without constraint; sexual attacks warn them that their bodies are not meant to be in public spaces, and racist and homophobic violence delimits the spaces of black and lesbian and gay communities' (Rose 1993). Research in London indicated that women over 50 are the least likely to use shared autonomous vehicle services: while men are excited about the technology of autonomous vehicles, women unsurprisingly are much more concerned with personal safety (MERGE Greenwich 2018).

A House of Lords report on Artificial Intelligence noted its differential effects on particular groups of citizens. They expressed concern for those often left behind by fast-moving technological developments: 'minorities, women, working mothers, disabled persons' who need to be included and prioritised. Other witnesses in the report pointed to truck drivers made redundant by autonomous vehicles who cannot simply retrain as, say, software engineers. Convoys of semi-automated lorries threaten the haulage industry's 2.2 million employees (House of Lords Select Committee on Artificial Intelligence 2018).

Neglected groups have been actively considered by some studies – including by our own GATEway project. Autonomous vehicles can increase mobility for non-drivers, such as people with disabilities and adolescents. In a typical community these represent 10-30% of residents (Litman 2018). A report by the Society of Motor Manufacturers and Traders focused on the needs of three groups – those with disabilities, older people and young people – who suffer most from restricted personal mobility. The challenges facing each group are distinct, but autonomous vehicles have the potential to increase their mobility, and improve their quality of life. The report claimed that autonomous vehicles would improve access to higher education for one million in the UK. But to achieve such benefits they called for a connectivity infrastructure across the entire road network (SMMT 2017). This inevitably invokes the notion of the ‘smart city’ and its potential to manage and enhance mobility (Buscher, Doody, Webb and Aoun 2014). A report for the Future Cities Catapult identified five main city challenges: population growth and stressed infrastructure, resource efficiency and low-carbon growth, resilient systems, income inequality, and demographic change and disease (Arup / Future Cities Catapult 2014); urban mobility solutions interact with all of these: it is impossible to separate the vision of the cities of tomorrow from that of the future configuration of their transport systems. In the past, mass-diffusion of private cars allowed low density and scattered urban developments, but diminished the quality of life in cities because of traffic congestion and polluting emissions (Alessandrini, Campagna, Delle Site, Filippi and Persia 2015). Potentially, the driverless car can reverse this urban deterioration.

There is a mutual relationship between autonomous vehicles and the environments and infrastructures with which they interact. Vehicles have an obvious and huge impact on the design, use and character of cities. Conversely, the changing design of cities, the visible and invisible infrastructures they provide and the policies that govern them, will have a large effect on the kinds of use – and therefore the benefits and disadvantages – that can be delivered by driverless vehicles. In developing our designs for future infrastructure, we have used the hopes and fears of citizens as well as theories around more inclusive, healthier and sustainable cities to show how autonomy can support people’s wellbeing, a more creative and caring urban economy as well as greater efficiencies and progress towards local, cleaner and greener services and systems. We have divided this chapter into three areas. The first focuses on the elements that make up the city transport system; the next looks at the impact of autonomy on city utilities; and the third on major elements of urban design.

5.2 Transport System

5.2.1 Roadways, pavements, cycle paths

City streets need to support pedestrians, cyclists, motorbikes, cars, public transport and private hire vehicles, as well as vehicles designed to deliver goods or support emergency services. This mix is controlled or complicated by roadworks, traffic management technologies and infrastructure.

In an autonomous future, an array of vehicles communicate with each other and the world around them to share their current and future intent together with knowledge about local conditions. Many journeys or logistical rules have been set in advance, and they know where people, parking and pick-up points are located and whether people or goods have requested a journey or if space is available for use.

As the following diagrams show, autonomy can alter the number of vehicles, the density of occupation within them, the distance between vehicles and the average speed at which people can move around town. Studies to date have shown that self-driving fleets of shared taxis can reduce the number of vehicles in a city to 10% of current numbers and this number can be reduced even further if public buses and trains remain in operation.

In dense urban areas, main arteries can be altered so that multiple lane roads can be remodelled to support higher levels of people movement using fewer lanes. In future

scenarios it may also be possible to switch lane directions so that peak traffic can make better use of interchangeable road directions.

In other areas, two-way streets can be repurposed as a network of one way streets, so that you can be dropped off or picked up close to your departure or destination point without having to contend with two-way traffic which can reduce speed without necessarily increasing access.

These changes allow significant areas of road surface to be re-imagined for a variety of purposes. These could include well spaced drop off points to help vehicles pick up and drop off passengers and goods, areas for vehicles to charge or wait without blocking the roadway, larger pedestrian areas, benches and resting places, more cycleways and cycle stores, pocket parks, linear green space, cafés and stores, recycling zones and on-street lockers for sending or receiving goods and mail.

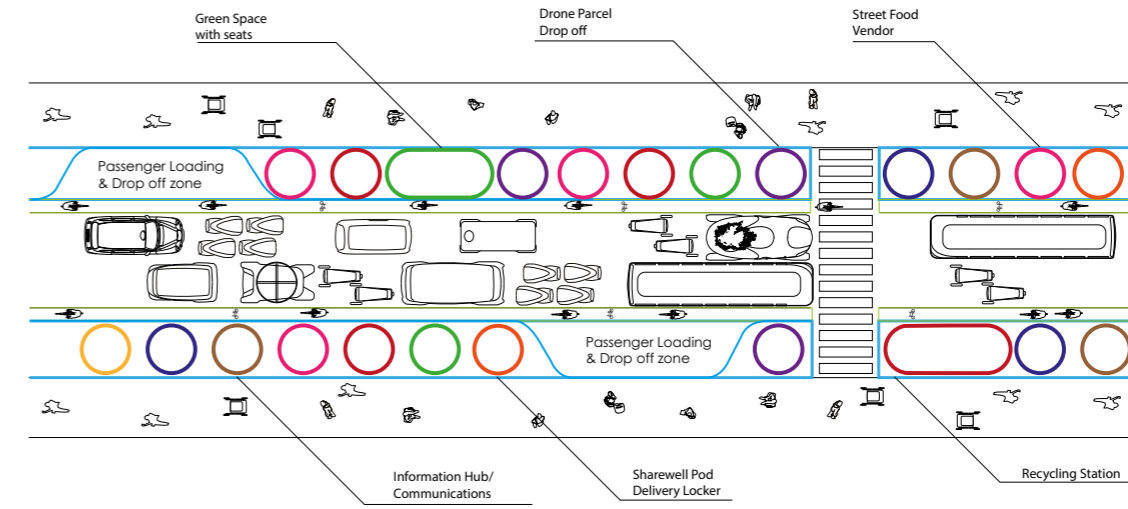


Fig 26: Four lane commercial streets could be redesigned to provide a more compact zone for public and shared driverless vehicles which can carry more people in less space. Multiple use space can be used for street markets, greenspace, pickup and drop off zones as well communication hubs, delivery lockers and recycling station

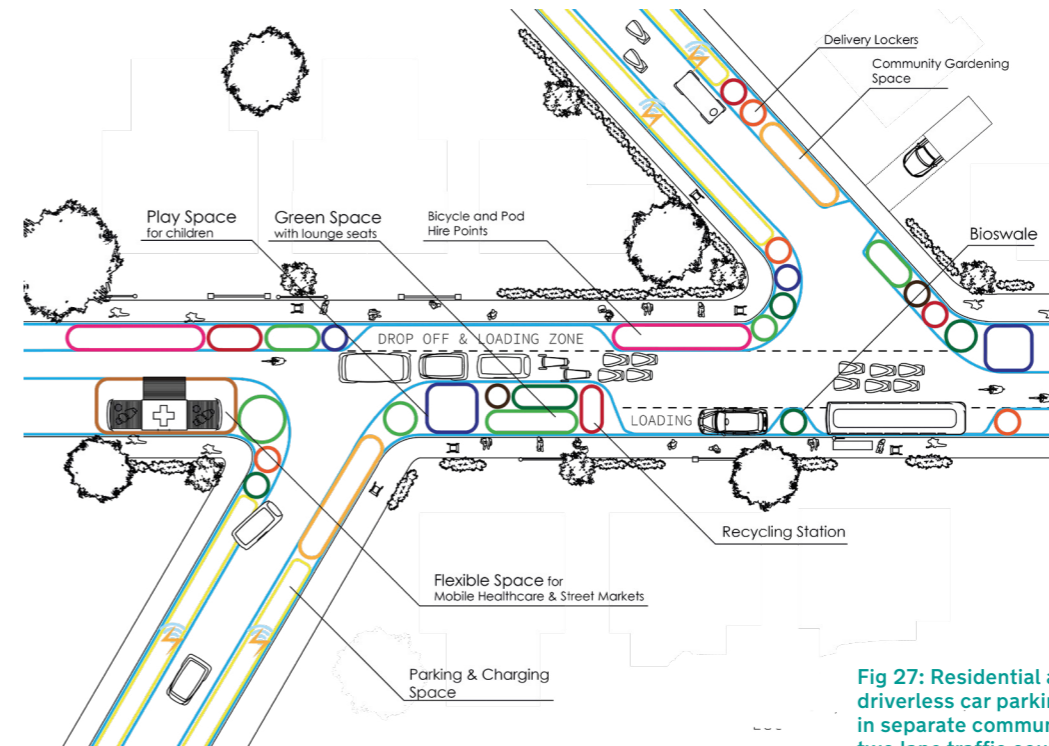


Fig 27: Residential areas could be re-configured to centralise driverless car parking and charging, either on side streets or in separate community car-parks. Streets that currently carry two lane traffic could be reduced to a single lane giving more space for pedestrians, cyclists and community activities

5.2.2 Parking and garages

The self-parking features of driverless vehicles open up opportunities for more thoughtful and carefully planned parking and garaging systems that free up roadside space for other activities while also supporting a more intensive vehicle charging system.

If, as predicted, personal vehicle ownership continues to fall in London and other urban areas, there will be fewer vehicles to park, store and charge.

In residential areas, London could promote the concept of 'Park-free' streets. Through collaboration with local people and pathfinder demonstration projects in a variety of settings, Park-free could change streets from places for vehicles to places for people and nature while still providing excellent access and support for everyone. Park-free streets will be provided with drop-off and pick-up points close to your home (or immediately outside for the disabled) and special zones will be created for charging, storing and maintaining a range of Electric and Autonomous Vehicles.

We assume that all vehicles in London will be electrically powered and will have self parking and other self-maintenance features. Vehicles will be able to manoeuvre out of each other's way to aid efficient docking patterns and Autonomous Vehicle store zones will be monitored to reduce vandalism or theft.

This re-imagining of streets will lead to a variety of novel streetscapes from play zones near schools and homes to linear parks, street cafés and street sport areas.

In central London and other commercial areas, underground and above-ground garages will be re-purposed to provide storage, charging and waiting spaces for driverless vehicles. They will also be modified to include cleaning and maintenance, especially where maintenance can be achieved through plug-and-play replacements rather than the relatively complex and dirty mechanics of traditional combustion engine machines.

Payment for parking and charging will be made using smart money that charges vehicles based on the electricity they consume and the time that they spend waiting. This charge can be adjusted to take into account the supply and demand for parking spaces as well as the supply and demand for electrical power. The charges will encourage Autonomous Vehicles owners to park and charge at night when peak demand is low or to make use of excess renewable power when it's available.

Public transport will still be the predominant form of mobility in London as it provides, after walking and cycling, the most compact and efficient infrastructure for moving large numbers of people through our congested city. It is also inclusive, good value and relatively frequent both during the day and at night.

With new rolling stock across the fleet, carriages and buses will be quieter and cleaner, more open and inclusive, with walk-through environments and wider doors, as well as improved comfort in the form of ergonomic seating, food and technology holders and air-cooling even on deep tube trains.

TfL will need to work with transport unions to integrate autonomous features into its fleet of trains and buses whilst ensuring safety and improving the experience of travellers and staff alike. Many trains and buses will operate with an autonomous driver (like the current DLR service) with TfL staff providing the human face of London – meeting, greeting and escorting travellers or acting as guides for those with additional needs. 'Quote of the day', 'Tube station gardens' and 'Poetry and Art on the Underground' will be as popular as ever and will be extended to include digital interfaces and engaging environments at transport access systems.

Large transport interchanges around major stations and cultural districts will need to integrate shared autonomous vehicles in a more comprehensive way, taking their lead from airports where pick up and drop off points are separated from parking, charging and waiting areas. This will lead to less roadside queuing and more just-in-time storage and retrieval services where driverless taxis and buses wait in adjacent garages or storage areas and only join the queue when passengers are nearby or as predicted by passenger management systems.

TfL may also integrate smaller Flexibuses into the network to provide additional shared mobility services in local areas. These will be particularly valued by people with additional needs but also help to join up larger transport interchanges in the outskirts of London where suburbs are less dense and larger bus or manned services are less viable.

Bus stops and other street-side infrastructure will have many community-focused features including colour e-ink screens that show local news and offers, real-time availability of transport as well as walking and cycling options for healthier living. They will also have tactile interfaces with Braille and audio visual support to order a bus or to book one of TfL's inclusive Workie taxis that can be used with TfL mobility card credits. These bus stops may extend to incorporate other communities features including mini-cafes, shops and on-street storage systems.

5.2.3 City logistics

Goods traffic is predicted to increase dramatically as more people make use of online shops and delivery services rather than physical shops. Some commentators believe that the number of retail shops will halve by 2030 and others predict that “Virtual reality will replace high street shopping by 2050”. Shops will therefore have to reinvent themselves if they are to survive and city planners will have to think more carefully about how parcels and packages are transported around town.

We have indicated the need to support both street and pavement based delivery vehicles that will have the ability to deliver to the recipient rather than to an address and will also be able to drop parcels off at a local store, in a street-side delivery box or inside a building using smart lock and gate systems.

These delivery robots will not only be able to drop off items but also pick things up. If they are well designed this will support and encourage greater levels of home production and product sharing. They could also be used to take reusable packaging back to its supplier rather than relying on a centralised material recycling system.

Rather than pay for drivers to sit in traffic, it's likely that distributors will focus on additional services that add value, such as unpacking and assembling items or using trust based locks to allow staff to drop off packages inside the home or in the boot of a personal driverless vehicle. Some of these services will be provided by the supplier to ensure that they can maintain and

extend their company's brand values, while others may make use of cooperative or private job-sharing platform providers.

5.2.4 Traffic management

Autonomous vehicles will respond to commands from traffic management services as well as send information to these services. This opens up the potential for a more responsive and intelligent management of vehicle movement at both a granular and a systemic level, as well as dystopian images of centralised control reminiscent of scenes from Minority Report.

In a preferable future, traffic management interfaces will help to manage the speed of vehicles to ensure that they do not exceed limits associated with schools, homes or commercial areas; control traffic lights to reduce the length of time that vehicles wait whilst ensuring that pedestrians and other road users are equally supported; alert vehicles when emergency vehicles are approaching; and reassign lanes' directions so that cities can reduce congestion during peak hours.

Services that manage traffic will also provide useful information to passengers so that they are aware of issues and can change destination or make use of other forms of transport if that is valuable. Just as Traffic Radio provides congestion updates, 'Traffic Intelligence' will provide updates about local traffic, pollution and potential problems ahead which can be integrated into various on-board navigation services.

Autonomous Vehicles will also be able to send information to the Traffic Management service although this is likely to be restricted to emergency and public service vehicles that have been registered to the service.

Further down the line vehicles will be able to communicate with neighbouring vehicles to ensure that they are 'paired' if they are going along the same route. This will allow vehicles to drive closer together and to ensure that they brake and accelerate together. The length of the vehicle chains will depend on the variety of traffic on the road as well as the needs of other road users with long chains seen on motorways and short chains allowed on city streets.

Black box systems within vehicles (and in the cloud) will store vehicle movement and other data as well as send aggregated information to the cloud to support accident investigations and other road management issues. The extent of data collection and its potential for both good and bad use will form a major ethical question for data specialists.



Fig 28: Transport interchanges in London will remain key hubs for communities and mobility within the city. They will support a wider variety of shared vehicles and the drop off and pick up zones will need to expand to support people's needs. Key issues include how they cater for additional needs and interact with pedestrians and cyclists, where and how they are stored when not in use, how they queue and access drop off spaces

5.3 City Utilities

5.3.1 Power / fuel

By 2035, we imagine that all vehicles entering the city will be electrically powered or use hydrogen fuel cells. The four remaining petrol stations in the central congestion zone will most likely disappear in the 2020s and most of those in outer London will have been re-purposed as fast charge stations or disappear completely.

The majority of charging points will be located on streets or in central garages or parking areas. Advances in wireless charging technologies may mean that most vehicles are now charged using wireless systems rather than plug-in power points. These systems will be mainly found in community parking areas as they can be used more intensively, rather than distributed across road networks; and vehicles will be able to access the charging system using mobile payment services and trust tokens.

Charging costs will depend on grid demand so most vehicles will be designed with batteries to support a day's worth of city use. Consequently they will usually be charged at night or during periods of low demand or high availability of renewable power. Due to the conservative nature of most purchasers and manufacturers, in-vehicle battery capacity will be higher than most drivers need and the spare capacity of parked vehicles will be used to meet peak demand by sending excess power back into the grid or directly into your home. Nevertheless, electricity for mobility will increase the demand for renewable power

and many manufacturers may build or purchase solar or wind power in parallel with vehicle manufacture so that they can guarantee that energy is available to meet future demand. This will also form an additional income stream to support their businesses, which will be seriously affected by the reduction in vehicle sales as ownership models are replaced by service and experience.

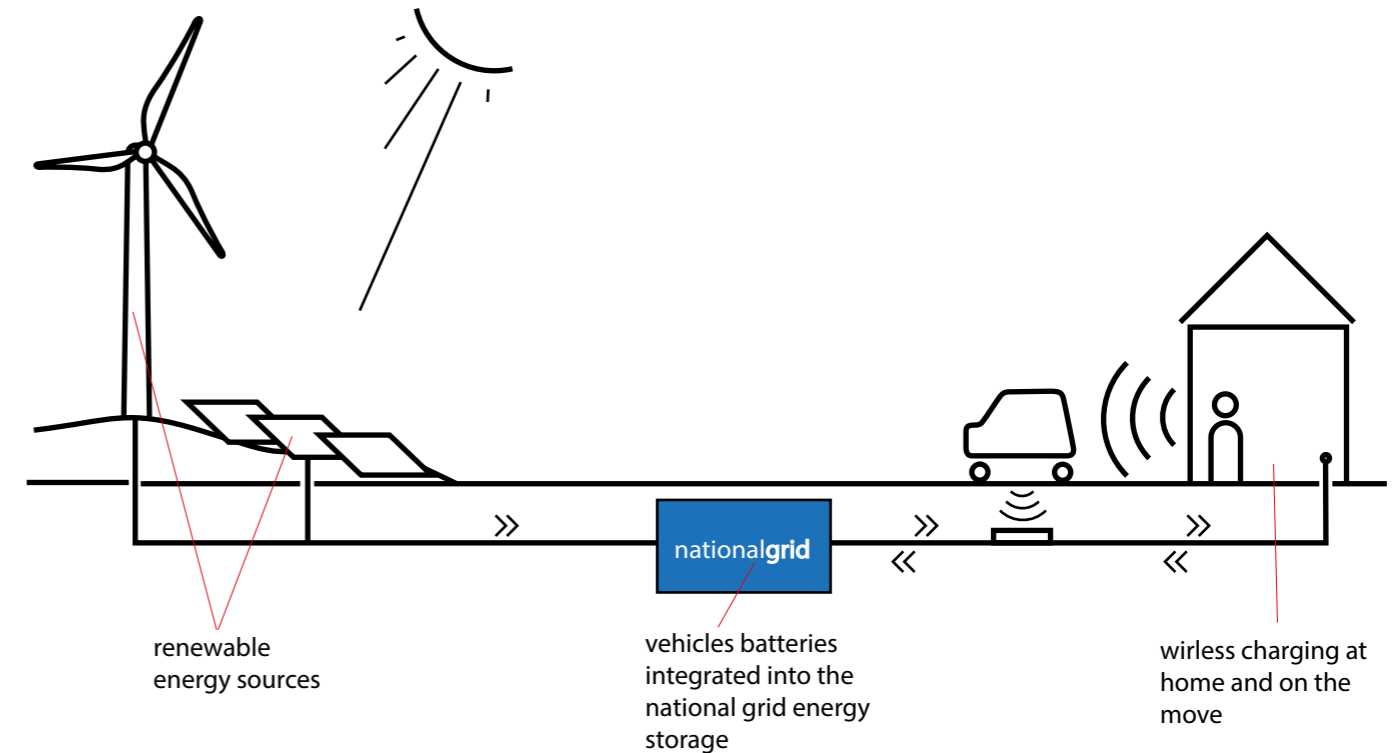


Fig 29: All driverless vehicles will be powered by renewable sources with on-board batteries providing power for motion and vehicle servicing as well as load balancing for the national grid. While individual householders may have charging at home, many autonomous vehicles will be charged in community parking areas that may also provide cleaning, maintenance and security functions.

5.3.2

Reusable materials and the circular economy

Zero waste is a philosophy that will become standard across cities. To support this approach to materials, local authorities will encourage the development of street, community and regional material recycling services.

They will encourage the sharing and reuse of products within the community and support reusable packaging including 'return to sender' using networks of package pods.

Residents will be provided with coloured and digitally tagged bin bags that help to sort material before it enters street recycling points and these points call for service when they are ready for emptying rather than using fixed collection times.

Staff who previously picked up waste and managed the collection vehicles have been retrained as street champions, who not only keep the streets clean and tidy, but also check on elderly neighbours when the weather's cold, look after parcels if people are away and help to keep the area safe and friendly.

London also supports the development of community based fab-labs that help to repair products and build new things using reusable materials. These fab-labs make use of delivery pods to collect and return broken items as well as sourcing raw materials for material recycling centres,

5.3.3

Information networks

Autonomous vehicles will become central to the information networks within cities. They will include sensors that capture environmental data or can be used as evidence in criminal cases . Many also act to provide mobile transmitters and receivers that create an ad-hoc information network that have supplemented the fixed transmitters that telecoms providers install on buildings.

As a result, there will be strict laws around data security and huge volumes of data will be stored in vehicle and transmitted to cloud-based data centres .

As this data can be used for commercial advantage there will be a continued and healthy debate between private providers and democratic authorities to ensure that data does not allow monopolies to control mobility within a city region.

London has led the way in providing a citizen-led marketplace for mobile services. This means that people can construct or choose their journeys from all the mobility options in the city - walking, cycling, bus and rail services as well as personal, community based and commercial autonomous providers.

5.4 Elements of urban design

5.4.1 Residential neighbourhoods

Residential streets will vary in character just as today but there will be a growing recognition of the possibilities provided by driverless vehicles and services.

While some boroughs will continue to prioritise resident parking zones outside each home, those with lower vehicle ownership will promote Autonomous Vehicles parking zones within 'park-free' streets. Through pathfinder projects, communities will experiment with re-planning residential streets based on residents' desires to share vehicles, make use of on-demand services and allow vehicles to park themselves in defined spaces for charging or storage.

This will free up street space for other uses including play spaces, green spaces, recycling zones, places to sit and chat as well as convenient pickup and drop off points that can be used by residents, flexi-buses, goods delivery and recycling vehicles.

Some communities will change from two way to one way street networks to increase the amount of space for other activities while others will incorporate separate lanes for cycling and mobility assisted vehicles.

While TfL will provide guidelines on how to create car park-free zones, communities will be able to create their own local specifications leading to a diversity of solutions that respond to local cultural differences and history.

In larger new developments, developers will be encouraged to limit private parking and to provide zones for shared vehicle charging and maintenance instead. Current street based facilities will be included in 'back of house areas' including material recycling and goods storage while streets will be designed with shared surfaces with defined zones in which vehicles can move. These zones will make use of carefully designed surface textures and colours to ensure that people with reduced vision are aware of where vehicles may be travelling.



Fig 30: Before and after view of typical residential neighbourhood near Greenwich. Two-way streets replaced by one-way lanes with additional space given over for sheltered pick-up points, delivery and drop off lockers, play zones for adults and children, more trees and shared bike stores



Fig 31: Residential streets may become 'car park-free' with driverless vehicles stored off-street in community car parks. What will residents do with this extra space? Here we show street play and community gardens while a family is picked up for a trip to the country, a mobile health unit connects with residents and an older person rides by on an autonomous M-Scot

5.4.2

Commercial zones

Local authorities will be inspired by the superblock strategy in Barcelona, the green squares of Paris and Oslo's private vehicle ban. But London is a city built around villages and it has older and more complex street patterns so the methods it may use to create a more liveable centre are more diverse.

Major shopping streets will be redesigned to support autonomous buses and delivery systems as well as the additional pedestrian traffic created by Crossrail. Multi-lane roads will be replaced by two-lane driverless zones with drop off and pick up points for buses, shared vehicles and delivery lorries at regular intervals.

Lanes that were previously used for traffic will be re-planned as seating areas, additional tree planting and street cafés. Delivery pods will transport goods to shops via pavements or back of shop lanes and many of these deliveries will take place at night.

Other areas that are already heavily pedestrianised may become vehicle-free village centres. Bicycles and smaller autonomous vehicles like the City zip and the M-Scout will move people around along designated routes designed for people and vehicles to coexist. Goods will be delivered to shops and restaurants by a variety of smaller vehicles including cycle services and pods.



Fig 32: Before and after view of Greenwich town centre. Dynamic lanes force autonomous vehicles to use central lanes outside of rush hour, allowing side lanes to be used for market stalls or reconfigured for street-side seating and planting



Fig 31: Commercial centres will become more pedestrian friendly with driverless buses and taxis navigating one way systems to pick up and drop off passengers, while smaller vehicles provide mobility for solo travellers or bridge human and electric powered motion

5.4.3

Squares, parks and green spaces

Since London was declared a city national park in 2022, communities and local authorities have been encouraged to develop plans to turn grey spaces green and to create a network of ecological corridors that support healthy activities and environments as well as biodiversity corridors that connect parks, nature reserves and waterways.

These green spaces have become increasingly important as London's temperature and rainfall increases. Trees have reduced extreme temperatures and bioswales have helped to manage local flooding. Since Autonomous vehicles have become more common and ownership has declined, green squares and street pocket parks have started to pop up across the capital and many of these follow quiet routes between neighbourhood parks or line major arteries that previously had serious noise and air pollution problems.

The consequences of planting trees, increased pocket parks and autonomous electric vehicles have been significant. Property prices along main roads have increased as they become more desirable places to live and there has been significant reductions in ill health from air pollution as well as reductions in London's mental health burden.

Autonomous services have also helped to make our green spaces more productive. Just as robots have been used to keep floors clean inside homes, roving cleaning, watering and mowing devices are now regularly used to supplement gardening and street cleaning programmes.

5.4.4

Airspace

The Civil Aviation Authority will continue to regulate drones and these laws will also apply to future autonomous drones. As such, drone use in London will remain limited to emergency services who may use them to deliver medical equipment or to undertake surveillance to support police services

Commercial drone operators may start limited courier services that make use of roofs on high-rise commercial offices to support just-in-time parcel delivery but these services will need to meet strict CAA together with urban noise and pollution regulations.

6.1 Patterns, problems, solutions

Our approach in this chapter is based on design patterns. We have used these to emphasise the generally applicable principles derived from our research. Christopher Alexander coined the term pattern language fifty years ago in his highly influential co-authored book on architectural principles (Alexander, Ishikawa & Silverstein 1977). The key features we have borrowed from his approach are (1) the idea of a set of reusable principles, and (2) that each pattern is interconnected with others.

While our research was focused on London, the patterns we derived can be applied widely and are usable by a range of actors in autonomous vehicles, urban planning and mobility. We have structured our design patterns around Political, Economic, Social, Technological, Environmental and Legal factors in an integrated PESTEL analysis. As in Alexander's original, patterns are not answers to questions to be solved in isolation. While each part of our PESTEL framework deals with a different aspect of future mobility, they cannot be developed independently. To make a technological decision about mobility will inevitably have implications that are political, economic, social, environmental and legal (and indeed ethical).

The Innovate UK initiative that led to GATEway called for “a focus, not on technology, but on researching and building a deep understanding of the impact on road users and wider society.” This human-centred approach is fundamental to the model of driverless car developments that we used in

the project. As becomes obvious on reading this present report, to deal with driverless cars is to deal with a sociotechnical system. This concept emerged in the 1950s when it became obvious that new ‘scientific’ approaches to industrial efficiency were omitting something vital: the human element. In some cases the introduction of ‘more efficient’ machinery was shown to have produced a less productive system overall because no one had properly considered the way that people - considered both as individuals and as social groups - would interact with the new machines (Trist and Bamforth 1951). Sociotechnical thinking takes an integrated view of people and technologies; in fact it prioritises human needs over mechanical efficiencies.

A related insight of design research concerns complexity and unpredictability. Most sociotechnical questions of any scale involve wicked problems. The term came into existence in the late 1960s when it became obvious that in fields like city planning there are no simple solutions with predictable consequences (Rittel and Webber 1973). Often, fixing one problem creates another. The characteristics of wicked problems include: that the problem is not fully understood until after the formulation of a solution; that we have no means of saying that problems have been definitively ‘solved’; solutions to wicked problems are not right or wrong; that each wicked problem is essentially novel and unique - we cannot simply transfer the methods or findings from projects we have already done to guarantee success; there are no realistic opportunities to try solving a wicked problem and then simply iterate another solution if the first solution is unsatisfactory; wicked problems have

no straightforwardly alternative solution. Importantly, views will continue to differ about which solutions are the ‘best’. Are we prioritising the needs of the technology industries - where competing claims could be advanced on the one hand for ensuring the continued health of UK automotive manufacturing or on the other for expanding digital car-sharing service businesses that would require far fewer vehicles? Or are we prioritising social benefit? And what might constitute meaningful social benefit? Is the priority one of wider economic benefits (which should in theory benefit all of society)? Is it overall health benefit, which in turn produces economic gains? Or is it benefit to specific groups who are effectively penalised by our current mobility solutions?

Society's choices concerning our current mobility systems include us tolerating over 180,000 road casualties in the UK per annum, including 1,792 deaths in 2016 (Department of Transport 2017). In the US, roughly 34,000 people are killed and more than two million injured in crashes every year (Bureau of Transportation Statistics 2018). Additionally each year, around 40,000 UK deaths are attributable to outdoor air pollution, with damage across lifetimes from babies in the womb to old age. The most vulnerable suffer the most harm: deprived areas often have higher levels of air pollution. Such health problems cost the UK more than £20 billion every year. Air pollution plays a key role in climate change (Royal College of Physicians 2016 xii-xiii).

Further choices lie in the distribution of the benefits of transport. With the private car and rail dominant, Britain's bus network has shrunk. Rising car use and cuts to public funding are thought to be responsible for a loss of 134 million miles of coverage over the past decade. London, the East of England and the South East are the only English regions to see bus mileage increase, while the North West has lost 23% of its bus network in a decade (BBC Data Unit 2018). One campaign group suggests that we live in a society prepared to abandon certain groups of people and leave them without mobility (Campaign for Better Transport 2015). The shrinking bus network leaves people unable to reach basic services such as shops and GP surgeries. The most recent UK government report confirmed the dire state of UK bus provision and the lack of a strategy for addressing it (House of Commons Transport Committee 2019). It has been suggested that in many areas the choices of jobs, schools, shops, leisure activities are so limited by the lack of public transport, that for many older people and others who cannot drive, their options resemble those available 200 years ago (Metz 2014).

Our current transport and mobility solutions clearly leave much to be desired. The benefits and disadvantages are shared inequitably. In the following pages, we identify many of the factors belonging to the PESTEL design patterns, concluding with a set of roadmaps that offer routes between current systems of city mobility and future driverless systems. Above all, we seek solutions that are better for all, including those neglected by current provision.

6.2

Design principles and patterns

Design patterns were first developed by Christopher Alexander in his seminal publication, *A Pattern Language: Towns, Buildings, Construction* and have been successfully adapted for a number of other design disciplines, especially the software community.

A design pattern is a re-usable form of a solution to a design problem. They are often organised into interlinking themes to create a pattern language.

While Alexander used 'scale' as an organising principle we have chosen to use the PESTEL Model as it helps us to find connections between design and a variety of other disciplines and forms of discourse.

The PESTEL framework considers the Political, Economic, Social, Technological, Environmental and Legal Factors that affect an organisation. In this case, we consider how these different factors affect the acceptance and adoption of driverless vehicles and how they might each help to increase their development.



Fig 34: Design patterns for future driverless vehicles should be both practical and delightful. Here, wider challenges are overlaid on a future public transport fabric sample designed by one of our textile design researchers

6.3 Political

Political patterns arise from the challenge of ensuring that autonomy meets the needs of the public rather than the needs of a specific section of society. Issues to consider include:

_____ Involving the public in the development and understanding of driverless vehicles

_____ Managing the transition from obsolete to new infrastructure and technology

_____ Considering the ethical underpinnings of driverless technology

_____ Understanding the implications on employment, leisure and nature of work

_____ Providing the infrastructure and planning framework in which future development will take place

_____ Considering the role of public services in the provision of future technologies

_____ Impacts on security

(Political) Problem	(Political) Solution
Driverless vehicles, like many new technologies, may focus on the needs of the wealthiest in society rather than the needs of those who are currently excluded.	Public bodies should advance the use of driverless vehicles to support those excluded from current mobility services by encouraging the testing and development of vehicles that support additional needs and by encouraging the development of driverless transport services that reach urban transport deserts and integrate with existing public transport services.
The general public may be concerned about the safety and appropriateness of driverless vehicles in urban environments.	Public bodies and stakeholders should encourage the involvement of the general public in the development, trialling, testing and deployment of driverless vehicles to ensure that future services meet their needs.

6.4 Economic

Economic patterns reflect the impact of driverless vehicles on the cost of mobility solutions, current and future employment and means of value exchange. Issues to consider include:

- _____ Affordable travel
- _____ What happens to workers whose jobs have been replaced by AV (Political)
- _____ Circular economy
- _____ Training for new and different employment (social) (political)
- _____ Employment
- _____ Cost of development and deployment (political)
- _____ Cars that pay for themselves by 'working'
- _____ Ownership
- _____ 24 hour access to the city (social)

(Economic) Problem	(Economic) Solution
Driverless vehicles will reduce demand for skilled drivers.	Strategies need to be implemented alongside the uptake of driverless vehicles to retrain people who are affected by the technology.
Implementing driverless technology within urban environments may cost significant amounts with indeterminate benefits.	The development of suitable infrastructure and public transport needs to be met by beneficiaries including service providers and public bodies.
Vehicles often sit idle when not being used by their owners, leading to 'wasted' value, increased road use and material consumption.	Driverless vehicles should be designed to support additional functions and services including 'shared mobility', 'energy storage' and integration with 'city logistics' systems.
Driverless cars will generate new jobs that demand new skilled workers including production, software development, maintenance and operation.	Training and education need to be developed alongside the implementation of driverless cars to make sure that demand for skilled jobs can be matched by the workforce.
Sharing and shared ownership will reduce the viability of road tax as a method to maintain and improve city infrastructure.	Flexible taxation models need to be considered looking at a wider range of variables such as time of travel, distance covered, environmental pollution and willingness to use less congested routes.
Driverless vehicles have the capability to operate efficiently throughout day and night increasing the impact of vehicle movement during night-time hours.	Vehicles need to be designed to operate quietly in order to reduce disturbance during night-time hours.
Working on the move is hard to do even in vehicles designed to support mobile workers.	Some driverless work vehicles should offer specific environments for people to work both together and individually.

6.5 Social

Social patterns of driverless vehicles reflect the opportunities associated with inclusion and wellbeing. Issues include:

- _____ Inclusion and accessibility for different people and needs
- _____ Social structures to prevent isolation
- _____ Car culture
- _____ Helping society as a whole
- _____ Door-to-door service for those who need it (technological) (economics)
- _____ Social connectivity through AV (technological)
- _____ Priority access for those who need it - radial drop off and pick up
- _____ Sharing
- _____ Will people still be allowed private vehicles
- _____ Making streets for people not for machines
- _____ Mass access to the full benefits of driverless vehicles
- _____ Preventing immobility and laziness
- _____ Mental health
- _____ Social spaces inside vehicles

(Social) Problem	(Social) Solution
Vehicles do not offer flexible, social space for travellers.	Interior spaces need to be designed to encourage social interaction.
Not everyone in the city is fully served by the current transport network.	The majority of traffic in the city needs to be connected and managed as one fluid system providing a connected series of public and private services for the people of the city.
Vehicle interiors do not offer the same level of comfort and facilities as our homes.	Interiors need to be considered as extensions of the home with the ability to provide home comforts on the move.
Disabled and partially sighted people can not access the full transportation network.	All future vehicles need to be fully accessible to all.
People using current vehicles are unable to make the most of the city around them. Lack of parking, congestion, and lack of accessible information whilst driving prevents them from getting the most out of the city.	Driverless vehicles need to be able to draw information from the city around it and present it to the occupants in an engaging and intelligent way.
Private vehicles promote isolation and are used by one person for a majority of the time.	Driverless vehicle typology needs to focus on shared vehicles that encourage social engagement both inside the vehicle and in the surrounding area.
Shared vehicles that do not have supervision are often dirty or vandalised.	Shared driverless vehicles need to be designed to have robust interiors, vehicles need to be inspected and monitored on a regular basis and a sharing culture needs to be nurtured.
Public vehicles are often less desirable because their interiors do not usually have the comfort or quality that private vehicles do.	Interiors need to provide the same or better levels of comfort that private vehicles do whilst being more robust, aesthetically pleasing, easily cleanable and resistant to vandalism.
Not everyone will want to give up driving.	Provision needs to be made within the vehicle, infrastructure and legislation to allow the people the choice to drive if they want to.

6.6 Technological

Technology patterns include the impact of controls, communication and materials on people's experience of driverless vehicles. Issues include:

- _____ Integrating driverless vehicles
- _____ Support and maintenance systems for driverless vehicles (economic)
- _____ Artificial intelligence
- _____ Human to machine communication and gestures
- _____ Networking
- _____ Fully integrated transport system
- _____ Flexible on demand services (social)
- _____ Holistic management of DVs to increase efficiency (political)
- _____ Pedestrian to Vehicle to robot hierarchy (social)
- _____ Scale and typology
- _____ Vehicles designed in context
- _____ Shared desirable interiors
- _____ Making the most of a fully driverless platform
- _____ Specialist spaces inside vehicles
- _____ Multi-purpose spaces inside vehicles (social)

(Technological) Problem	(Technological) Solution
Fleet vehicles need to be maintained and stored within the city with increasing demands on space.	Intelligent 'movement scheduling' needs to be implemented to make the most of the space and resource flows across the city.
Driverless vehicles need space to maintain, refuel and park themselves within a city environment.	Communities and organisations need to create centralised service zones at local rather than support
Vehicle platforms do not offer an efficient use of space.	With the removal of a driver, vehicle footprints and packaging can be more compact and take up less space.
Delivery vehicles often struggle to get the goods they are carrying to the final destination.	The scale of vehicles needs to be considered depending on the need of the service being provided, and the access the vehicle will need, to provide door-to-door service.
Current traffic system does not work together for the greater good of the city's movement.	All on road and pavement vehicles need to talk to each other to help manage traffic in a holistic way to provide the best movement of people and goods as possible.
Not all road infrastructures will be relevant or required for the use of driverless vehicles.	Strategies need to be put in place to run alongside the uptake of driverless vehicles, adapting infrastructure needs ahead of the demand.
Congestion in London is at saturation point and wastes time, energy and money whilst increasing pollution.	All autonomous vehicles need to be interconnected to provide the best possible flow of traffic throughout the city.
Driverless vehicles are not trusted to make the right choice in the case of an accident.	Driverless AI needs to be tested in the digital and physical world with a certified 'licence' being awarded.
Driverless vehicles do not have the ability to make eye contact or make gestures when communicating with others, as human drivers currently do.	Driverless vehicles need to behave and communicate in an understandable way, signalling their intentions with the same or greater dexterity as human drivers.
Driverless vehicles have no way of communicating the nuances that human road users, cyclists and pedestrians have.	A universal language needs to be implemented as an extension of indicators to allow driverless vehicles intentions to be recognised by all ages and abilities.
Digital driverless services are not always visible to those who are disabled, partially sighted or without access to a smart device.	The supporting systems that provide the information and 'touch points' for driverless services need to be visible and legible for all.
What happens when something goes wrong?	Multiple fail safes need to be designed into the vehicles and surrounding infrastructure to protect people
What happens if a driverless vehicle is hacked?	Multiple fail-safes need to be imbedded into existing vehicles to ensure the safety of occupants and the public.
How can we prevent passengers from vandalising or misusing a public driverless vehicle.	Public driverless need to be monitored and checked for misuses and damage.
How do we prevent other road users and pedestrians from 'bullying' driverless car?	Driverless cars onboard AI needs to be robust enough to with the natural flow and integrate into existing driving cultures and patterns of the city it's operating in.

6.7 Environmental

Environmental patterns consider the impact of driverless vehicles on the environment and infrastructure of a city as well as wider ecosystem consequences. Issues include:

- _____ Infrastructure
- _____ Environmental impacts
- _____ Pollution
- _____ Systems and flow (political)
- _____ Road networks (political)
- _____ Pedestrian zones (social)
- _____ City sprawl
- _____ Positive street design for healthy living
- _____ Vehicles that are an extension of home (social)

(Environmental) Problem	(Environmental) Solution
Too much of our urban and residential space is used for parked cars that are not being used.	Future streets need to have more flexible spaces that focus on the improvement of the wellbeing within the community.
Driverless technology has the potential to reduce the need to be physically active within the city.	Walking and other physical activity needs to be considered an integral part of public driverless vehicles and supporting strategies need to encourage people who are able to integrate physical activity into their journeys.
Vehicles are not always designed with their habitat in mind.	Vehicle manufacturers need to consider and design for the context of which the vehicle will be used in.
Busy streets with large pedestrian volumes often end up with conflict between pedestrians and traffic.	Busy areas need to be pedestrianised while maintaining vehicle accessibility to the area.
Private vehicles services do not work in conjunction with the rest of the city's transport network.	Private vehicles need to be integrated into a wider transport scheme, provide additional public services.
Cities will grow and grow once people are happy travelling long journeys in comfortable driverless vehicles that look and feel like home.	Planning permission will need to be carefully regulated to prevent city sprawl and driverless vehicle design will need to be focused on improving the mobility of the current urban environment rather than encouraging longer distance journeys.
Driverless vehicles may make some infrastructure redundant and require new supporting infrastructure in its place.	Strategies need to be in place before driverless vehicle arrive on the streets to manage the transition between driven and driverless vehicles.

Legal patterns consider the impact of driverless vehicles on existing legal principles. Issues include:

- _____ Insurance
- _____ Rights of motoring
- _____ Surveillance and civil liberty (political)
- _____ Responsibility for damage and injury
- _____ Legislation
- _____ Taxation models (political)
- _____ Fail-safes for Driverless vehicles when something goes wrong (technological)

(Legal) Problem	(Legal) Solution
Smaller delivery bots could overwhelm pavements and prevent people from wanting to walk.	Bots need to be regulated to prevent them taking over the roads and streets with bots following a predictable format or a 'code of pavement conduct' so pedestrians know how they will behave.
People under the age of 18 are not permitted to travel in vehicles without supervision.	Legislation needs to be adapted to allowed under 18s the full range of autonomous travel for both private and public travel.
Driverless vehicles will have the ability to see everything in the immediate vicinity in and around the vehicle.	Structures need to be put in place to allow youth to access driverless vehicles via proxy supervision or via linked accounts.
Unregulated drones and pods could take over our streets and skies.	Legislation will need to be put in place to regulate data streams that are gathered from driverless vehicles and uphold citizens civil liberties.
	All delivery services will need to be regulated with a clear hierarchy of where and when they can travel and who can operate them.

6.9 Design-led roadmap for adoption

The following road-maps offer routes between the current systems of city mobility and future driverless systems, taking into account people, technology, infrastructure and the environment. We have divided this roadmap into three phases. They are based on our current understanding of technological development, attitudes to new technology and the capacity for vehicle manufacturers and cities like London to adapt. Some cities and environments will adapt more quickly either because of demand pull or supply push.

Phase 1 – 2015-2025

The first phase of development can be characterised as a period where trust is built between service providers, citizens and other stakeholders. Expectations will need to be managed and it is likely that we will see early adoption of driverless services in areas designated as ‘car free zones’, in campus developments and for specific services such as campus travel and some forms of logistics. There will also be trials and pilots of intra-city passenger services including trial local bus services and trial taxi services.

Phase 2 – 2025-2035

The next phase of development will see greater levels of inclusion and significant changes in public perception. This may include personal mobility solutions and vehicles that support additional needs together with services that provide new experiences for the general public such as flexible bus routing based on user demand and needs.

Phase 3 – 2035+

In the medium to long term, driverless vehicles and services will become a mature and significant component of mobility solutions in urban and rural environments. We see autonomy everywhere and, where political will and personal demands are apparent, these services will support ‘green and intelligent city’ infrastructure and embrace wider social and environmental agenda.

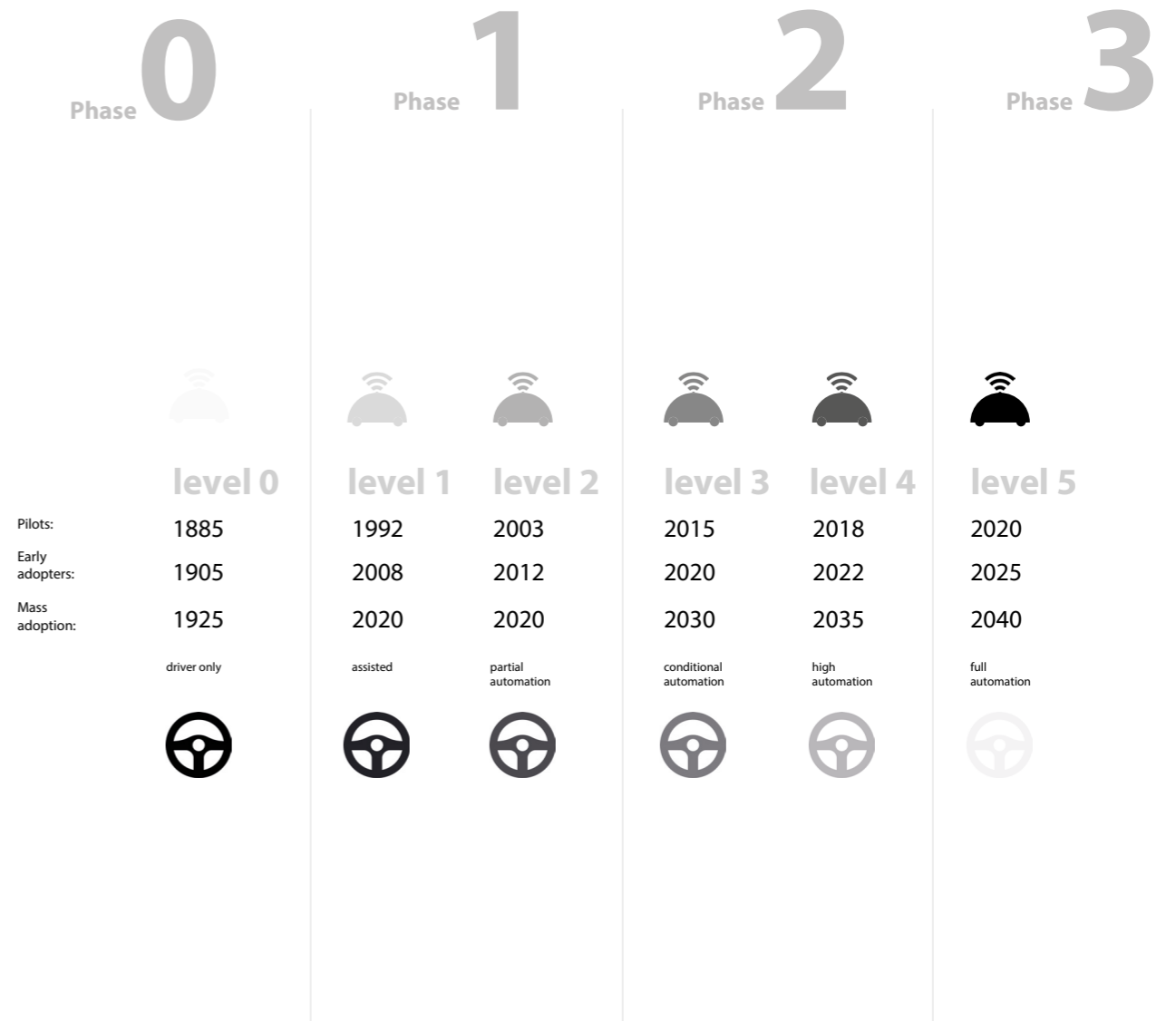


Fig 35: The five stages of autonomy broken down into 3 phases. While level 5 pilots may be available in 2020 it's unlikely that they will achieve mass adoption until the 2040s. In defined city centre environments, autonomy could arrive more quickly, with early adopter neighbourhoods, business parks and communities integrating fully shared level 4 autonomy as early as 2022

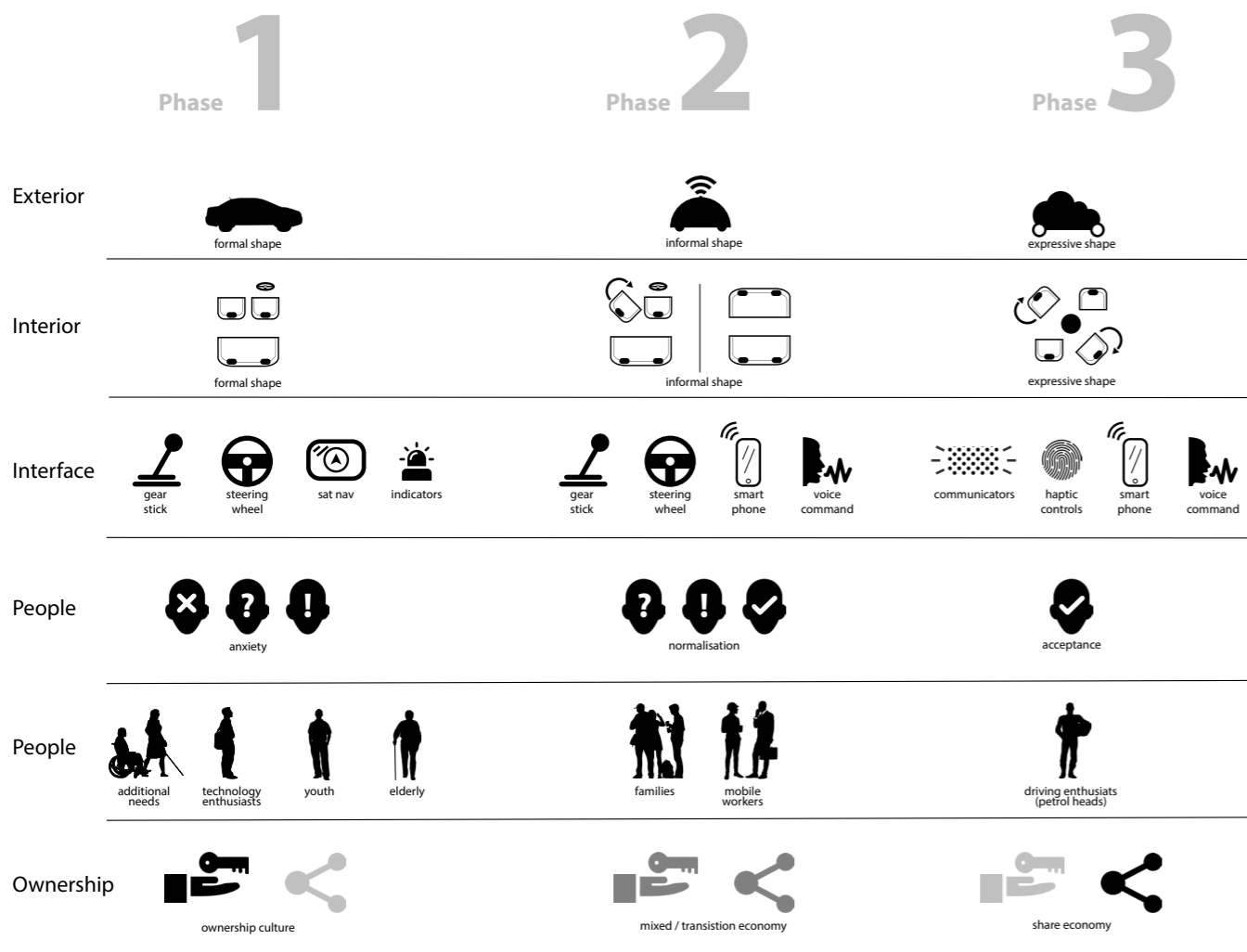


Fig 36: The first adopters of autonomy may well be the young, the old and those with additional needs, who can benefit from shared and inclusive public transport in dense urban centres. Ownership may move from a dominant to a secondary model of mobility and vehicles themselves will become more expressive of internal functions, dominated by connected and intelligent technologies

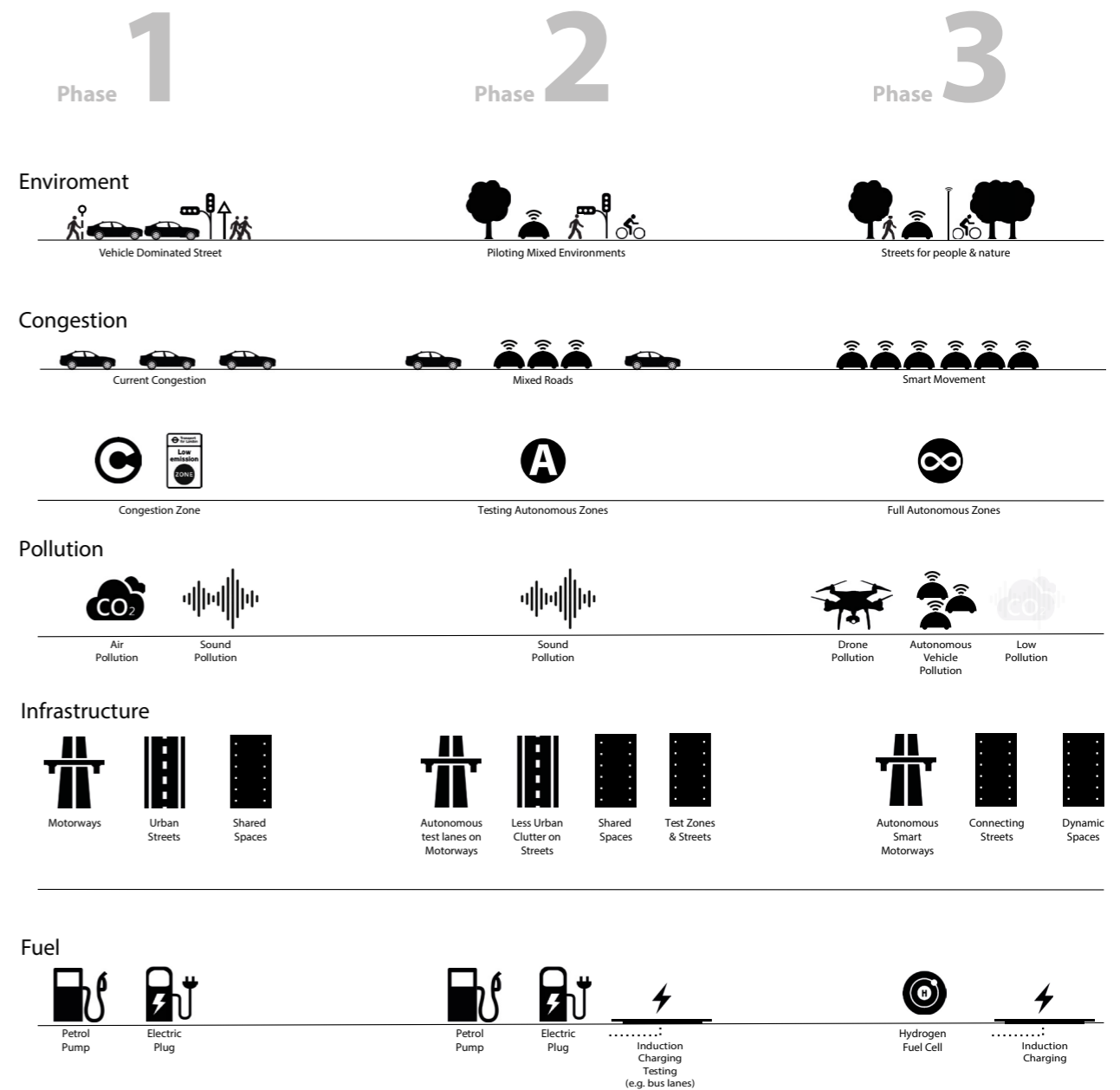


Fig 37: As vehicles become smarter, safer and more autonomous, cities can adapt to provide more shared streets, where vehicles move together intelligently, in less polluted and more dynamic environments. Petrol stations will disappear to be replaced by induction and hydrogen charging technologies

7.0

Research Methods

This chapter of the report outlines the methods we have used to learn more about the attitudes and aspirations of citizens and professional stakeholders. We share the methods and the key learnings that came from these research techniques.



We used a range of methods within the GATEway project through processes of design research. Some of these methods are familiar from other disciplines, such as reviewing the existing literature: we looked at academic studies relevant to driverless cars. As we have indicated, the field of relevant knowledge is wide, including not only technology, design, and social attitudes and behaviours around driverless cars, but also the planning of cities, research on the service economy, on digital innovations, on accessibility and on attitudes to autonomous systems more generally. We benefitted by exchanging our developing insights with our partners in the project, including the project lead, the Transport Research Laboratory. Also within GATEway, the University of Greenwich investigated pedestrians' responses to driverless vehicles (Hulse, Xie & Galea 2018), while Commonplace, an SME specialising in consultation tools for planning, used sentiment mapping and other technologies to elicit live responses from members of the public to the vehicles, located in time, place and context (see Boyd Davis & Saunders 2014). We looked not only at academic publications but also at the 'grey' literature, including manufacturers' publicity materials and popular culture views of driverless vehicles, from journalism to films to comic strips – particularly historically.

In addition, we created designs. It is important to consider why. What roles does design have in a project like this – what are the designs for? And who is the designer?

What roles does design have in a project like this? An obvious function of design is to please the senses, particularly to please the eye. It makes a difference if some particular design of driverless car is repellent to most people while another design is attractive. Visual appeal is a crucial component of acceptability and adoption. The battle over governments' impositions of plain packaging on the tobacco industry vividly illustrates this. Neither side in the dispute has doubted that attractive appearance is immensely persuasive, and that plain, drab appearance contributes to a loss of appeal (Hammond 2010). But there is much more to design than visual attraction. We can think of design in the roles of instantiation, iteration, interrogation and provocation. These kinds of design research are not quantitative: they have no statistical validity. They prioritise depth over breadth, and insight over generalisation and reproducibility.

A key role of design is to instantiate abstract ideas, allowing us to 'get real' about something that would otherwise be just a concept. H.A. Simon was one of the first to point out that, while the traditional academic sciences are predominantly concerned with understanding what already exists in the world, design research includes the alteration of that world. Design intervenes in – and alters – the world it is studying (Simon 1969). Once we see a designed proposition, even in rough sketch form or as a digital wireframe, we can react to it. It becomes a focus for discussion and deliberation. Even for designers themselves the externalisation of ideas in visible, tangible form is a powerful aid to thinking, a two-way bridge between the problem and the solution (Cross 2001, 2004). Solutions can be thought of as 'conjectures'

that designers use to explore both the problem and the solution in tandem (Cross, Naughton & Walker 1981).

After the early instantiation, designing often then proceeds by iteration, with increasingly refined developments on the basis of the initial version – but sometimes with radical departures, especially when multiple stakeholders are involved beyond the designer. Archer, a pioneer of Design Research at the Royal College of Art, remarked that 'during the course of the problem solving activity new objectives may tend to form and reform' (Archer, 1968: section 2.29) and that 'the complete set of objectives is only rarely definable at the beginning of the project. Most of them emerge by mutual consent as the project progresses' (Archer, 1968: section 6:15). Designers need the freedom and ability to shift their aims as a deeper understanding of the problem and solution evolves (Cross 2001, 2004).

Key benefits derive from sharing early instantiations with others. One of the ways we did this was through the exhibition described in 7.4.2. There we did not set out to 'sell' the concept of driverless cars, but to provoke discussion. Individual designs, and the overall design of the exhibition, focused on interrogation and provocation. Dunne and Raby outline the kind of design which is not about problem-solving or aesthetics. They particularly criticise the in-built optimism of so much design, advocating instead design as a means of speculating how things could be: 'This form of design thrives on imagination and aims to open up new perspectives on what are sometimes called wicked problems, to create spaces for discussion and debate

about alternative ways of being, and to inspire and encourage people's imaginations to flow freely' (Dunne and Raby 2013: 2). A useful image here is of future cones. Here and now is thought of as a point: an increasing range of possibilities is pictured as the widening of a cone extending into the future. Taylor described such a 'cone of plausibility' (Taylor 1990), in which particular scenarios lie on future planes slicing across the cone at increasing distance. Hancock and Bezold (1994) refined this model to include four main classes of future – not just the possible, the plausible and the probable, but, crucially, the preferable – based on a taxonomy of futures by Henchey (1978). Voros shows how the preferable does not necessarily lie within the volume of the probable – it may equally well intersect the preposterous, a zone about which people say 'It's impossible, it won't ever happen!' (Voros 2017). The plural title of our exhibition *Utopia or Dystopia: Driverless Futures* made clear our intention to embrace not only the best of futures but the worst. It cannot be overemphasised that the exhibition was not just communication to the public. It also engaged with the public. Itself based on thoughts and opinions gathered from the series of workshops we carried out in 2016, the exhibition was designed as a further opportunity to stimulate visitors, engage with them, and elicit their ideas. Four workshops during the exhibition covered topics such as how the inside of vehicles might change if entertainment and play become as important as driving and safety, how driverless vehicles might look if parents feel comfortable allowing their children to use them, and how the architecture of the city might respond to these new vehicles. Dystopian visions included the accelerated death of the High Street,

driverless cars with aggressive driving habits, human isolation away from shared forms of transport, and systems that track the user's every move and leave her vulnerable.

In the exhibition we asked visitors to illustrate their hopes, fears and dreams, and what solutions we should consider in trying to avoid a dystopian future. And as we have explained, we ran a series of workshops, in the exhibition and at the Greenwich location of the vehicle trials. The Greenwich activities took place in part long before any of the project's vehicles had been seen, while others were structured around live experience of the vehicles by workshop participants. These workshops were not simply consultations or focus groups, but invited participants to help co-create visions of future mobility. This raises the second big question related to our methods: Who is the designer? Simon, already quoted, is famous for his suggestion that 'everyone designs who devises courses of action aimed at changing existing situations into preferred ones.' As we discussed in 6.1., this simple proposition is difficult to achieve in practice. We will not always know what courses of action will produce an improved situation, or even know that we have reached the preferred state, and, worse, there is the problem of who is doing the preferring: few solutions are optimal for everyone, and often significant groups are disadvantaged by the 'preferred' solutions. Nevertheless, Simon's view – that anyone aiming to transform the world to a better place is in a sense designing – was important for our research in GATEway. Though the RCA is a world-leading design university, we do not think we have all the answers: often the best people to propose solutions are those most directly affected.

This is particularly the case when the life experience of the users is outside that of the designers. Given that designers are often young, privileged and without significant disabilities, this mismatch occurs all too easily (Coleman 2007). A solution to this problem is co-design, which has its roots in the Scandinavian participatory design movement of the 1960s (Beck 2002). A key principle of the participatory design approach is the assumption that the users themselves are in the best position to determine how to improve their circumstances. It turns the traditional designer-user relationship on its head, viewing the users as the experts, and the designers as consultants and facilitators (Czyzewski, Johnson and Roberts 1990). Any special expertise – whether held by designers or others – becomes another resource to be drawn on, not a source of power (Schuler and Namioka 1993).

Our background research included a review of papers that examine autonomous vehicles from a design and technology perspectives; an analysis of the history of driverless technologies; and a review of emergent themes from research colleagues in California, where driverless cars are already on the road and in daily use in Mountain View, outside of San Francisco.

What we did

We carried out desk research to understand the technical features of autonomous vehicles, organisations involved in the field and predictions about future autonomous design features from automotive and technology companies including, amongst others, Google, Mercedes and Tesla.

We also reviewed national and international mainstream media sources from journalists and public commentators and created a time-line of state of the art and historic milestones for different types of autonomous vehicles from around the middle of the 20th century until today.

Following this review, we mapped out and classified the perspectives and dimensions emerging from media journals. Key themes around benefits and concerns emerged, which we divided into journalist and general public categories.

What we learnt

Themes ranged widely from social challenges including crime, anti-social behaviour and ethics to economic issues around employment and data ownership. They also highlighted intriguing possibilities around impacts on city environments and transport infrastructure, as well as the detailed design of vehicle interfaces, sensors and interiors.

1. Crime, anti-social behaviour and legal activities;	"All good until pranksters cover those sensors up with duct tape and you end up with driverless EVs in a lake" Anonymous member of public
2. Convenience & consequences of using autonomous vehicles;	"Driverless cars' potential to reduce crashes, cut back on energy consumption and pollution, and provide 'last mile' mobility to disabled, elderly, or poor people who aren't able to drive. Minimise the 'cost' of congestion" Anonymous journalist
3. Private data & autonomous technology;	"Imagine a malicious hacker taking over a car (or worse, a whole collection of cars) and programming it to drive at high speed into the nearest large collection of people?" Anonymous member of public
4. Owning and sharing vehicles in the cities and rural areas;	"Many benefits '1 shared autonomous vehicle could replace 11 conventional cars'. Designers shift to considering other activities. Commuters will recover time to be productive, connected or entertained in news ways" Anonymous journalist
5. Accidents and mortality rate;	"Won't save thousands of lives unless everyone switches. I've never had accident so why would I switch with all its limitations?" Anonymous member of public
6. Safety, weather conditions & emergency scenarios;	"Autonomous Vehicles do not get drunk, fall asleep, get road rage, get distracted" Anonymous member of public
7. Ethical decision making & responsibility in an emergency situation;	"If the self driving vehicle has to choose between running over a child or head on hitting a truck and killing the passenger what happens? Someone has to program those choices." Anonymous member of public
8. Driver jobs and new types of service opportunities;	"The driverless future will transform both the literal landscape and the start-up landscape. Just like the iPhone created a whole new ecosystem for start-ups with the App Store." Anonymous journalist
9. Road infrastructure, vehicle to vehicle & vehicle to infrastructure communication;	"The car, in turn, would communicate with the sensor-equipped roads it drives on, offering its passengers the ability to pay extra to go in faster lanes or unlock access to shortcuts" Anonymous journalist
10. Autonomous vehicles' effect on the urban environment;	"Major cities won't need as many large parking decks. McKinsey estimates that by 2050 up to 5.7 billion square meters of parking space could be converted to other uses." Anonymous journalist
11. Cost in mobility;	"Autonomous Vehicles will charge more when demand is highest (to balance latency). This would reduce if people could work when available but many can't." Anonymous member of public
12. The vision and implication for insurance and law;	"Governments would lose fines, because cars would obey all traffic laws, but police forces would need fewer officers on the road, and prisons would need less capacity as drunk drivers kept their freedom." Anonymous journalist
13. The technology benefits and concerns;	"Until we get technology and processors that work in the same way as the human brain then this driverless technology will not be full scale adopted." Anonymous member of public
14. Control of autonomous vehicles and concerns over privacy of personal data;	"Data on your movements/shopping habits/visits/malls/hospitals/ relatives/lovers etc. will be sold to the highest bidder." Anonymous member of public
15. The vehicle exterior and interior design;	"Designing a new type of space 'third space' that exists between the home and work. Require new interaction for both work and play. Mix of shared and owned third spaces" Anonymous journalist
16. Strong views & attitudes towards autonomous vehicles and current driving experience;	"It will further the class divide" Anonymous member of public

7.2.2

Stakeholder interviews

What we did

We held interviews with partners within the GATEway project and other experts with knowledge relevant to driverless vehicles. The aim of these interviews was to understand their vision for autonomous vehicles and systems and to compare this with wider public perceptions. Experts included representatives from Transport for London, RICA – a UK research charity that focuses on needs of older and disabled people, Telefonica – a telecommunications provider – and RSA – a global insurance company.

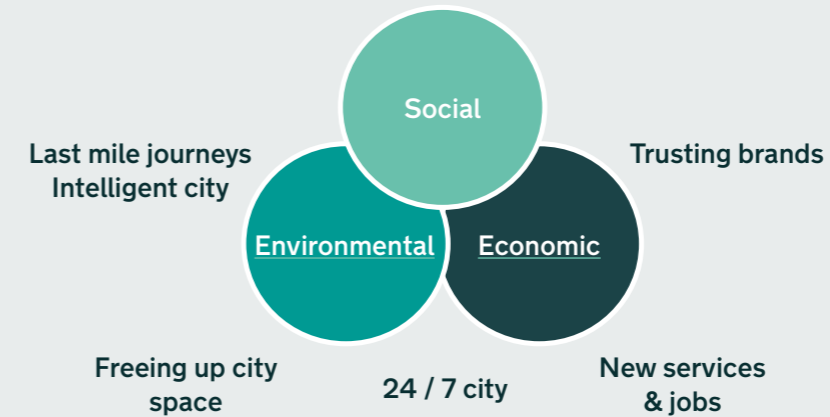
What we learnt

Opportunities highlighted through these interviews included the ability to support a wider range of people and journeys including the disabled and last mile connectivity; transformation of the urban environment as shared vehicles use space more efficiently and are able to operate 24/7; and ways in which these vehicles will create new jobs, new services, new brands and new businesses.

Concerns that were highlighted included social challenges such as the community value of bus stops and the impact on other road users including cyclists; loss of employment and the changing nature of employment and training; the ways in which private services might increase congestion by competing with public transport or use data to manipulate public behaviour; and the infrastructural challenge of dealing with a mix of driven and driverless systems.

Expert Interview: Opportunities

Design for anxiety, acceptance by younger generation



Expert Interview: Challenges

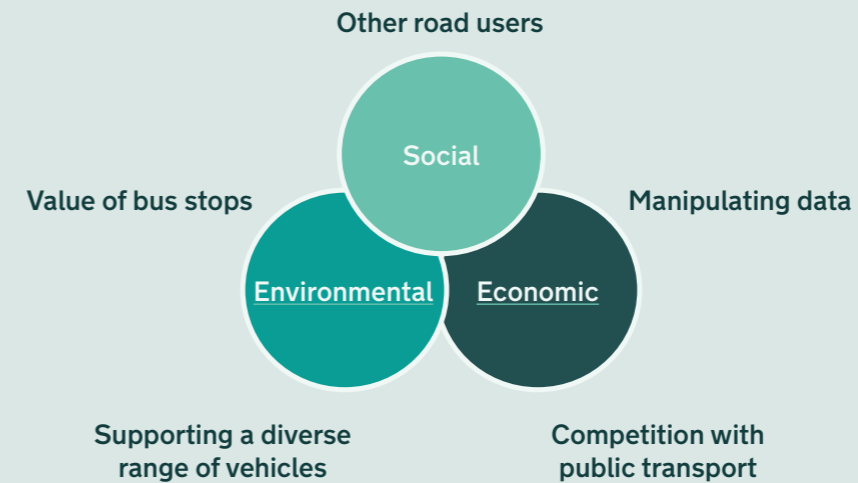


Fig 38: Expert interviews identified opportunities and challenges across social, economic and environmental domains

7.3

Studio projects

We also carried out design projects with vehicle designers at the Royal College of Art both through summer internships in summer 2016 and a follow-on project with first year vehicle designers during autumn 2016. These activities created future designs, models and provocations that we used in a public exhibition in Spring 2017 at the London Transport Museum as well as providing an opportunity to bring to life some of the creative ideas that were developed with members of the public during our pre-trial workshops.

A secondary report outlining these activities in more detail will be issued as an addendum to this main report.



Fig 39: Students and interns developed a range of future driverless vehicles. Here, researcher, Daniel Quinlan, investigates the proportions and personality of a driverless delivery pod

7.3.1 Intern projects

What we did

The adjacent diagrams show the themes that we used to inspire a group of vehicle design interns during the summer of 2016.

We asked them to consider what vehicles would look like if they were designed for children or if they were designed to support those with additional needs. What impact will driverless vehicles have on city architecture and on public services like health and security; how will future vehicles deliver food and other goods; and how will they communicate with each other and the world around them?

Along with personal tutorials and independent research, we gave the interns the opportunity to facilitators during our public pre-trial workshops. This gave them insights into people-centred methodologies as well as viewpoints from other perspectives.

What we learnt

Vehicles that they developed included city pods that herd together on larger roads and split up into individual units for the last mile. Connected cars that provide additional services beyond transportation; gesture vehicles that nod, wink and purr to signify what they are planning to do; vehicles specifically designed so that families can play or chat together on the move; extended mobility vehicles that make it easy for wheelchair users (or parents with prams or heavy shopping) to get in and out, and luxury vehicles that represent the modern equivalent

of the human powered litter – where the wealthy are carried by intelligent robots as if the robots were modern day slaves.

Further solutions look at the underlying needs and desires of Londoners and the implications of changing safety requirements in vehicles. Some vehicles support millennial activities like immersive 3D virtual gaming environments and concerns around physical fitness - a treadmill car or a bus that contains gym equipment. Another example considers what couples will do in a taxi when there is no driver to watch over them...

Beyond vehicles for people, interns and students imagined new ways of enabling city life with a range of useful (and not so useful services) from automated street cleaning and autonomous dog walking to on-street vending and mobile market stalls that can run without an operator. They imagined bins that go to the depot to be emptied, mobile silence machines that absorb construction noise and mobile barriers that herd people across busy junctions to ensure that VIP driverless vehicles get priority.

Delivery pods collect content from mother ships that in turn collect parcels from central depots. City skies are filled with various drones. Bee bots pollinate trees and plants; adverts are beamed down on passers-by based on their online profiles and the neighbourhood they are walking through. And drones are put to use by security and health services too.

The adjacent images show some of the detailed design solutions that have been developed including new vehicle forms and

typologies, provocative images suggesting new journey experiences and challenging interpretations of how these vehicles might communicate with their passengers and with the world around them. Many projects were used as raw material for our public exhibition and to help the design and research team to respond to the opportunities and challenges that we found through our research activities.

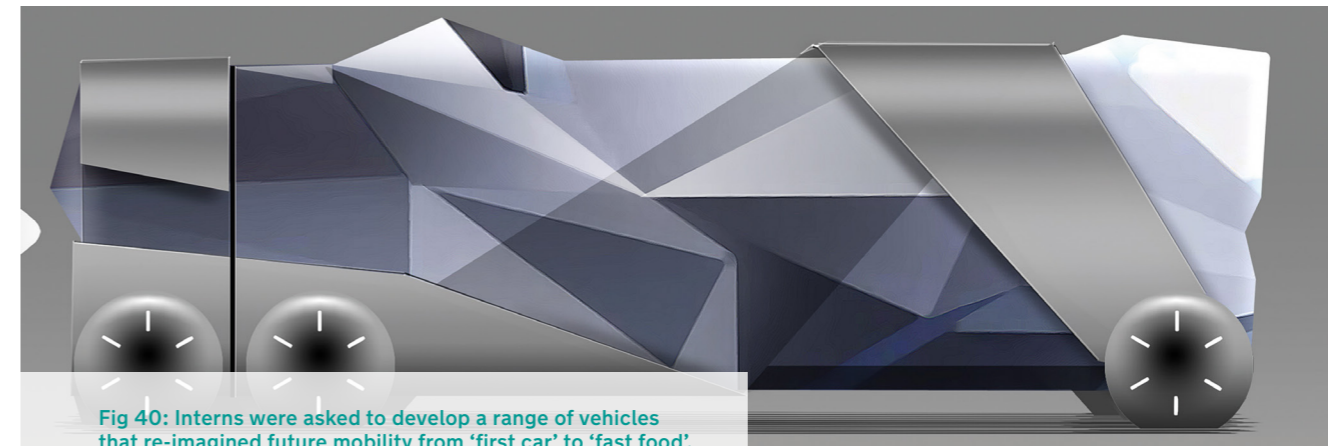
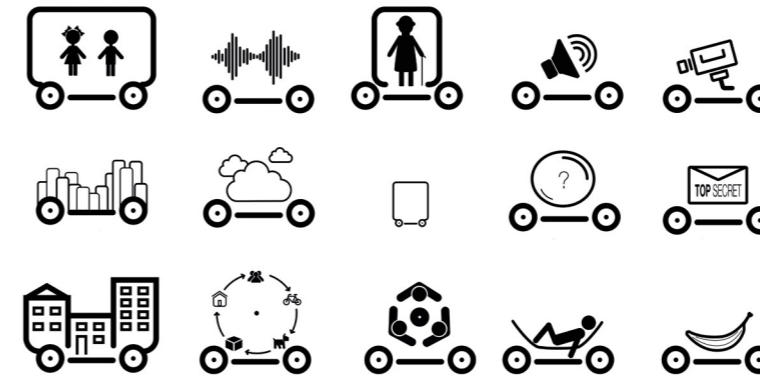


Fig 40: Interns were asked to develop a range of vehicles that re-imagined future mobility from 'first car' to 'fast food'. Clockwise from top left: themes for driverless research; an initial concept sketch from researcher Sam Johnson, looking at designs for ageing and inclusion; a future bus with a dockable pod from researcher Paul Piliste

7.3.2

Student metro projects

What we did

We briefed first year vehicle and textile design students to engage with public perception of the driverless future. They were asked to carry out individual research; isolate specific issues; and present their findings and proposals through visual images and storyboards.

As part of the project we used the framework of our pre-trial workshops to help them to identify their own hopes and fears for driverless futures. We also introduced them to a number of our public participants so that they could see the world through a different set of eyes.

What we learnt

The solutions that they developed assumed that future vehicles and streets would be intrinsically safe and accident free. Their solutions included climbing frames that kids ride on the way to school, recycling trucks that automatically sort and prepare waste for reuse as they collect it and vehicles that support learning outside the classroom or provide shared workspaces for use on your commute across town.

The textile design students looked at the challenges of an ageing population focusing on the needs of people suffering from arthritis and dementia. They mapped out issues around these conditions and developed textiles and physical spaces that would reduce the stress and increase the visual accessibility of driverless environments.

Major themes that emerged from these studio based projects included:

- Urban and trans-city typology divergence
- The scale of driverless vehicles
- Logistics vehicle market
- Impact of autonomy on city infrastructure
- Public services rather than public transport
- Human to vehicle communications

The projects also gave the next generation of vehicle designers the opportunity to immerse themselves in the possibilities inherent in driverless systems, setting them up for careers in design agencies, OEMs or as future entrepreneurs and educators.

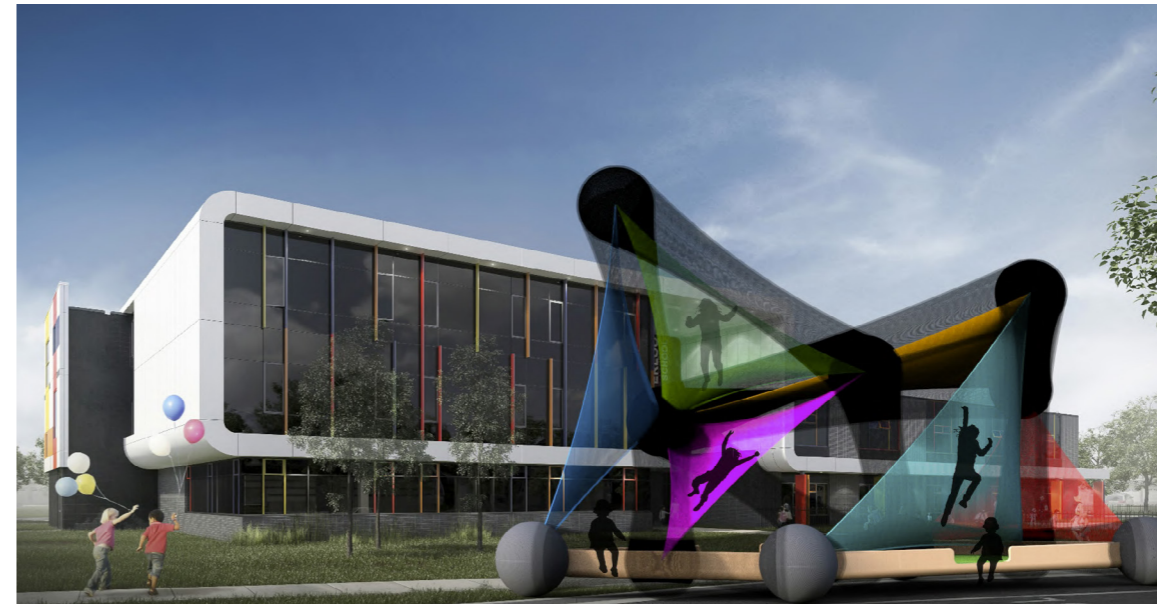
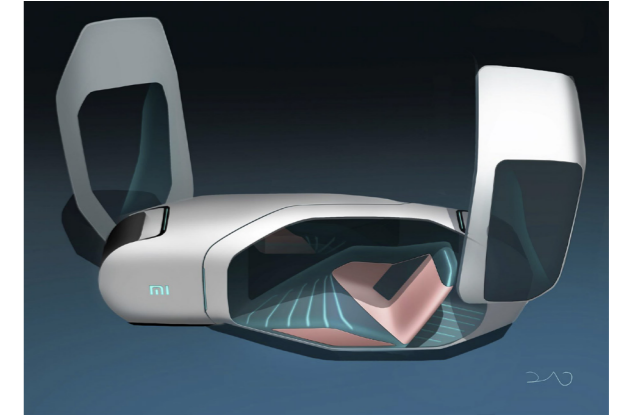
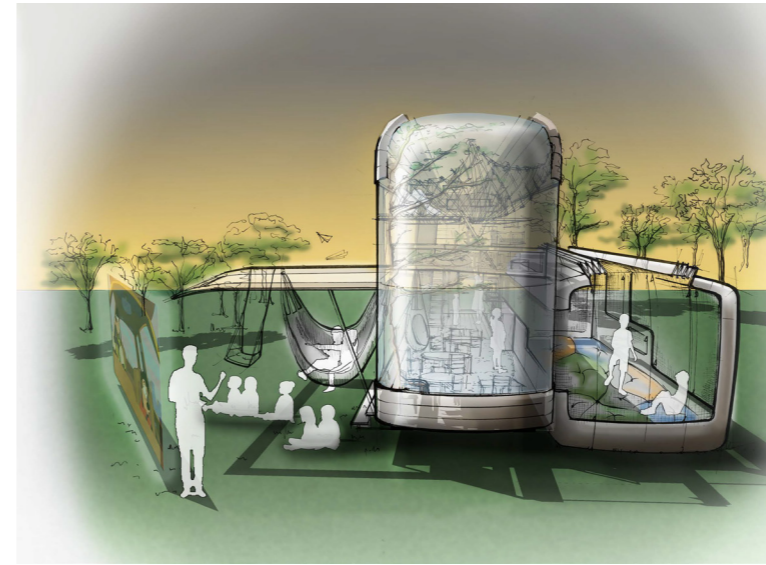


Fig 41: First year students in the vehicle design department imagined vehicles that were inherently safe. Clockwise from Top Left: student Irene Chiu developed a mobile classroom that provides teaching on the go, on-site and in the field; designer Bin Sun developed the 'introduce yourself' project as a reaction to the isolation that can often be experienced in large metropolitan areas; the Passing Playground project, by student Arash Shahbaz imagines a mobile climbing frame that kids could catch on the way to school

7.4 Public engagement

In order to better understand people's attitudes to driverless vehicles we spent time with members of the public in pre-trial workshops in summer 2016 and during public trials in the spring of 2017.

7.4.1 Pre-trial workshops

What we did

Over a two-month period in summer 2016 we ran eight public workshops in North Greenwich. With the support of TRL, 109 people were recruited who fell into the following categories: drivers, non-drivers, enthusiasts, professional stakeholders and those with additional needs. Five workshops were focused on these specific groups and the rest were open to people from any category.

Before the workshops we gathered people's views on current travel and goods movement in London via online questionnaires.

During the workshop we collected information about their current attitudes towards driverless vehicles and their hopes and fears for a driverless future.

Working in small teams, our facilitators helped them to describe the problems that occur on their current journeys around time and then, using their hopes and fears, imagine how future driverless vehicles might overcome these problems and create more delightful experiences.

Finally, they worked in teams of two to construct future vehicles using Lego, plasticine, pens and their imagination.

What we learnt

Through these activities, we learnt that a significant majority of our participants had a positive attitude to driverless vehicles despite their lack of knowledge.

Attitude to driverless technology

We also learnt that they felt that driverless vehicles would be safer than driven vehicles, that more people would use shared autonomous vehicles rather than owning them, that they would be a cost effective solution to urban mobility and that they thought they would be cleaner and greener than current road vehicles.

Attitude to driverless vehicles

Their hopes for driverless vehicles included streets that were safer for people and city animals as well as free from the dangers of drunk, rude and dangerous drivers; they imagined that vehicles might be an extension to one's home rather than a place to move you from A to B; vehicles would improve the environment by taking themselves for a service automatically and free up space on our streets for people rather than machines; provide on demand transportation that would be smaller and more personal than centralised infrastructure; and that future journeys might be more comfortable, fun or productive as a result.



Fig 42: During the pre-trial workshops, members of the public created a checklist of dream features for a driverless vehicle and worked in pairs to build a future AV using Lego, paper and their imagination

Their fears included worries around the challenges of interacting with a machine especially if you are disabled; less opportunity to personalise vehicles if they are shared; an increase in anti-social behaviour when there are no drivers around to monitor behaviour; and the concern that cities will grow and public transport will be threatened as driverless service providers deliver vehicles that can travel further distances while passengers rest. They also worried about the impact of cheaper

door-to-door services on their physical and mental health, either through reduced physical activity or through the isolation that single person driverless pods might add to their lives.

The future vehicles created by public teams showed that people see driverless vehicles in a completely different light to existing transport services, more akin to mobile homes, workspaces and hotels than cars, buses and trains. Features included easy access, adequate space for people, pets and luggage, personalisation of entertainment systems and interior furniture that would support different types of activity. Sensory environments were important for everyone but especially valued by those with additional needs. Many imagined these vehicles as 'services' rather than 'products' that they would order just in time depending on the journey that they were taking; and the vehicles themselves were supported by a range of just-in-time support services including separate goods vehicles, mobile food delivery systems, maintenance and refuelling systems that were connected to and controlled by intelligent assistants.

7.4.2 Driverless Futures Exhibition

What we did

From 3rd March to 23rd April 2017, the RCA presented an interactive design display as part of London Transport Museum's Designology exhibition that explored the world of driverless vehicles.

Driverless Futures looked at peoples' aspirations about driverless vehicles as well as their concerns by using the narrative of four fictional characters and scenarios based on future potential journeys.

Rather than using the exhibition to sell the benefits of this technology, we used the space as an environment in which visitors could explore the potential impact of these vehicles on their lives. We used peoples' hopes to imagine a positive future - safer, cleaner and more inclusive - and their fears to describe a dystopian one - isolated, mechanistic, driven by profit and exclusivity.

The aim of the exhibition was to engage with the public in a creative and open debate, to encourage visitors to comment on the ideas that we presented and to develop further opportunities and challenges that we might take forward in follow up design activities.

Alongside the 'Driverless Futures' display, we produced four pop-up events that offered visitors a chance to meet designers from the RCA and explore the impact of autonomous vehicles in our everyday lives.

During the 6 week exhibition, we welcomed approximately 30,000 visitors, collected around 1,500 ideas and held a debate with experts from Transport for London, the Royal Society for Blind Children and the Institute of Chartered Engineers as well as designers and architects from transport design and urban planning. The exhibition was reviewed in the *London Evening Standard* and *Car Design News* as well as a number of online blogs and social media sites.

What we learnt

We asked people to say what they would like to do in driverless vehicles and tell us about their hopes and fears for the future.

As befits a predominantly family audience, the answers were both useful and surprising. Major hopes included faster journeys, less pollution and fewer accidents. Their fears included more accidents, lost jobs, obesity and artificial intelligence takeover. While travelling, parents hoped to have more time with their children rather than concentrating on the road ahead, but many imagined that they would have time to nap, opportunities to eat or drink and space to dance, sing and rock out!



Fig 43: During the Driverless Futures exhibition at the London Transport Museum, researchers ran a series of workshops with members of the public looking at a range of topics. In the 'Cars for Kids' workshop we considered what driverless vehicles might look like and if parents would feel comfortable allowing their children to use them alone

Fig 44: Exhibition Utopia and Dystopia images. Will the future be a dystopian one – where jobs are lost, high streets closed and machines track our every move? Or can we create a positive future where autonomous machines increase access for all, drive productive wellbeing in our society, improve our environment and, as the American writer Richard Brautigan hoped 50 years ago, ‘watch over us with loving grace’?



7.4.3

Driverless Shuttle Trial workshops

What we did

Our last research activity offered 50 members of the public the opportunity to ride in our driverless shuttle, nicknamed Harry, on the Greenwich Peninsula. We used props to prototype future commuting, shopping and leisure journeys and asked our participants to act out future scenarios, explain what they liked and didn't like about the experience and the journey and then describe what a future vehicle might look and feel like for them.

The future commute included an opportunity to work on your tablet, do some exercise or meditate after a busy day; the future shopping trip included time to write out a shopping list, wrap up a present and have a massage; and the future leisure journey imagined a trip to a party where you eat some snacks, play a game and dress up for a fun night out.

Participants then worked with our researchers to discuss the shuttle experience – considering the interior, vehicle attributes, environment requirements, and service needs. They used this information to create a checklist for a future vehicle and a mood board that described what it might look like and how it would feel.

What we learnt

“Practical, Magical, Reliable”

Our participants were excited by the opportunity to ride in Harry and were not worried about the technology. Their major concerns centred around prototype weaknesses – slow speed, beeping sensors, harsh braking, tech failure, noisy and bumpy ride; and the experience itself – facing away from the direction of travel, uncomfortable seats, lack of leg room, obscured views that disconnect them from the outside world, limited storage space, lack of journey and route information and poor temperature and personal environmental control. If these problems were solved and they were provided with wi-fi, charging points, fold down tables, cup holders and a big bin for waste, the vehicle would have been seen in a more positive light.

As in our previous research, our participants mainly preferred affordable public transport with the minimum number of changes and smooth journeys facilitated by Oyster cards and steadily improving journey-planning information. Dislikes included pollution, traffic and over-crowding during rush hours. If all goes well, journeys are opportunities for ‘down-time’ to read, listen to music or catch up with social networks. People with additional needs felt that transport services were still not designed for them, while many felt that public spaces prioritise vehicles over people, making walking less accessible or convenient.



Fig 45: We asked 50 members of the public to imagine future journeys in our autonomous vehicle. What would they like to do on future commutes, shopping trips and leisure journeys around town? We worked with people including those who were young and old, able and disabled, drivers and non-drivers

Of the future activities that we tested, many would be happy to use a tablet on a fold-out table, have more comfortable support to nap or be at ease, de-stress with an app or physical device, have a drink if they had a cup-holder, or chat if travelling with friends to a party. They generally did not want to do things that made them feel uncomfortable with strangers or cause motion sickness. These included exercising, eating, dressing up or falling asleep on a short journey, although some were happy with the idea of putting on make up or even meditating if the environment was right.

When thinking of future vehicles, two thirds wanted to use public transport as their main form of transport, a fifth imagined using private hire vehicles and the remaining 15% would like to own their own vehicle although over half of these would lease them out to others when they didn't need them. This points to a future London with significantly fewer cars on the road and stiff competition between public transport and various types of private hire vehicles. If public space becomes more attractive and functional, we also see the opportunity to increase the number of people who walk and cycle in line with the Mayor's healthy streets strategy.

“Reliability is the utmost importance”, “Reducing the waiting time is the best benefit” “Door to door and bookable” “I have no desire to own a vehicle, driverless or otherwise, and it would be very expensive”, “If I was making a routine journey. I would prefer a shared public service, however if it was a one off, I would pay extra for a premium” “I want a model which allows me to use differing vehicles for different trips”

Older participants preferred to use public shared vehicles especially as they value their freedom pass. Personal wellbeing and comfort were key factors and most wanted grab handles, charging points, upright seating with armrests, cup-holder and tables. Ideally vehicles would have secure spaces for luggage, shopping and wheelchairs or prams and easy access with wide doors and ramps to deal with height differences. On short journeys participants wanted to read or watch the world go by, while on longer journeys some might choose a lounging chair so that they could nap, watch a movie or eat a small meal. On longer journeys they would also appreciate an on-board toilet and a place to get ready in privacy.

“I like to look out and read”, “I would like variety, especially to be able to stretch”, “I would like maximum flexibility to do what I want including socialise”

People with additional needs would mainly choose a shared service at low cost. All five people with additional needs wanted to use public transport for some of their journeys but half would like to have a vehicle they can lease out or make use of a premium taxi service. Around 30% would pay a premium price for a private service. Vehicles should be comfy, homely and reliable with softer chairs and armrests with space to relax or be productive. Beyond features mentioned by older people they would appreciate additional space for crutches, coats, umbrellas as well as rucksacks and other luggage. The interior should have scene lighting, big front windows to see where they are going, an information console (audio/video) about the journey and a big screen to mirror phone content. Most expressed the desire to rest while travelling/



Fig 46: Stills from video footage taken while participants tested out future activities including eating, drinking, sketching, playing, resting and sending emails using tablets and mobile phones

“I would like to be seated, reading a book and listening to music, lounge when feeling tired”

Families preferred to own a vehicle, as trips with the kids are regular occurrences that often require additional belongings like toys, snacks, nappies, bedding and pets. They also often live in suburban areas with poor public transport options. Overall, families would like their vehicles to bring comfort to the journey and entertainment for all the family, but with a key focus on the children.

Future autonomous vehicles should be greener and more efficient at getting around town as well as providing multifunctional spaces to suit different moods and activities. Most people wanted practical, playful (fun/entertainment) and relaxing environments that could support entertainment and education as well as practical things so that they could spend meaningful time with their loved ones.

Seating should swivel and be adjustable so that families could choose how to orientate themselves – to look out, spend time together, read or sleep. Beyond the features mentioned by other groups, families wanted playful environments if they were possible as well as better individual environmental controls both for safety and for comfort. Most systems should have tactile and mobile device interfaces for convenience and in case of damage.

“My little ones have little legs and they struggle to walk the 15 minutes there and back. It’s always the coming back that’s always hard”, “Additional belongings is prime because you need that, whether my son likes it or not he still has to take it.” “I’d hope not

to need seat belts, but you know, if they are required then they are. I would also like a bin with a lid to dispose of half eaten bananas or whatever. A climbing frame or wall. Because distracting a child with a screen is fine but if it could be something else.”

Families in particular wanted more control over route navigation, emergency situations and parking. Some were concerned that they should be able to take control if their child was unwell or they decided to change their plans, while others felt that too much control would cause more delays and congestion on the road. They also spent more time talking about the sort of information that they and their family might need both for comfort and reassurance. This included traffic updates; news; weather; route display; local information and ETA so that they didn’t have to constantly answer, “Are we there yet?” Information could be presented via large screens, audio interfaces or via mobile devices.

“The emergency stop can be automated. If there is some kind of emergency what do you do? The child can get sick on the way, there could be something on the road. You can’t foresee the things. I would like to have an emergency stop. It gives you control.”

Families wanted materials to be cleanable and comfortable; blinds or electronically tinted windows to control glare; flooring made from wood strips, vinyl or carpet, although they recognised the challenge of keeping it clean; seating might be made from textiles, leather or even cork.

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Younger participants wanted to use shared public services although 15% would pay extra for a premium service. Most planned to spend their time on their mobiles, being entertained or staying in touch and nearly half said they might also eat or do something educational. Vehicles should be comfortable, provide private space if possible and allow them to swivel around to look out or chat with friends. As with other groups tech support, multi-sensory controls and features that help you to study or snack in comfort were key.

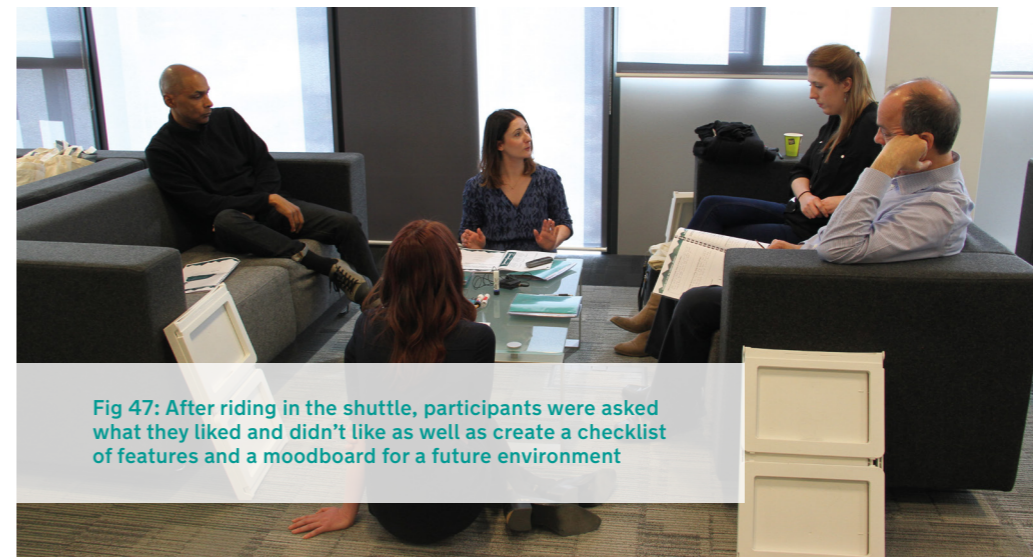
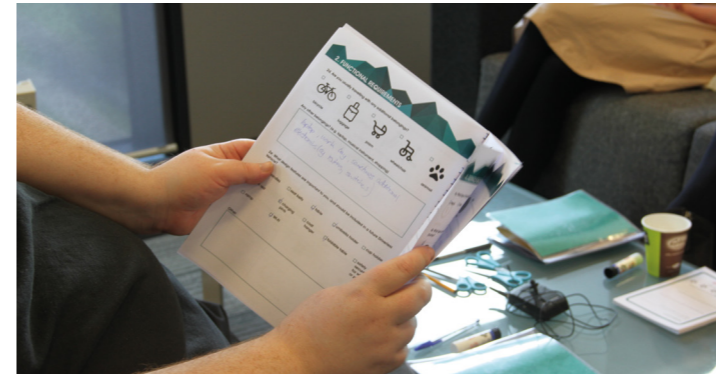


Fig 47: After riding in the shuttle, participants were asked what they liked and didn't like as well as create a checklist of features and a moodboard for a future environment

8.0

Future Research Opportunities

The work that we have undertaken during the GATEway project has shown a huge interest in the potential of driverless vehicles. The people we met are positive about the value of the technology and feel that, with the right principles and designs, they will not only support more inclusive, comfortable and useful journeys but also help to solve some of the most intractable urban challenges including safety, efficiency and reduced pollution as well as wider social and environmental issues.



8.1

Research Opportunities

Research by the Royal College of Art for GATEway is relevant to:

- Policy makers
- City planners
- Transport authorities
- Automotive manufacturers
- Mobility service providers
- Charities and advocacy groups
- New entrants to mobility, particularly digital innovators

The Context for Future Research

The UK Government's recent Industrial Strategy White Paper (2017) outlined four 'grand challenges' – artificial intelligence and the data economy, clean growth, ageing society, and the future of mobility – with the intention to make the UK a world leader in each. While GATEway's research is highly relevant to the future of mobility, it is also important for the other three challenges. Our research has shown the relevance of autonomous vehicles to an ageing society through the potential to provide improved social interaction for older citizens – and others neglected by current forms of transport – through increased mobility. Autonomous transport exploits Artificial Intelligence not only at the vehicle level to endow it with independent navigation and control, but at street and city level through smart roads and the provision of integrated transport solutions. The CAV – Connected Autonomous Vehicle and its digital infrastructures will be a key part of the data economy. Not only will effective

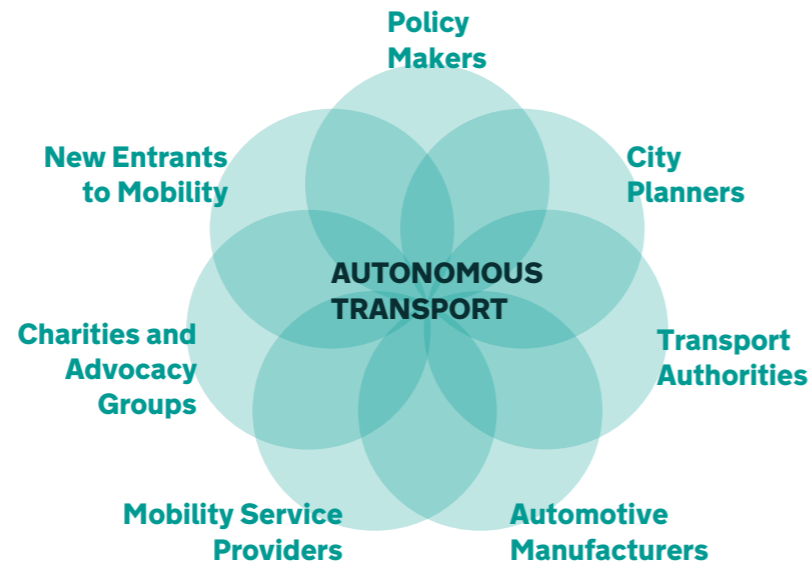


Fig 48: Venn diagram of the Royal College of Art's research relevance in GATEway

transport and mobility solutions rely on the data economy, they will feed into it through the creation of new, and currently unforeseen, forms of business and social enterprise. And autonomous vehicles have the potential to do good – or harm – in the search for clean growth. Whether or not they are a benefit to the planet will depend as much on social attitudes to shared mobility services, and on policy and legislation, as on technology.

Industrial Significance

The automotive sector is a significant element of UK economic well-being. UK automotive turnover in 2016 was £77.5bn; the industry employed 814,000 people across the UK; it exported products worth £40.1bn, 13% of the UK's total export goods, adding £22bn in value to the UK economy and thus Britain's largest sector in terms of exports by value. Eight out of ten cars made in the UK were exported: the UK exports to over 160 markets worldwide, more than half to the EU. There are more than 2,500 automotive component providers in the UK with 82,000 people employed in the UK supply chain. The growth of CAVs, connected and autonomous vehicles, is expected to lead to £51 Billion value added annually by 2030 with 320,000 additional jobs, 25,000 of them in automotive manufacturing (SMMT 2017). In the top ten sectors for Foreign Direct Investment in Europe, the UK is the leading destination for software, business services, automotive assembly, financial services, and food (House of Commons Library 2017). It is noteworthy that software, business services and automotive lead the list, given the need for expertise in all three to make autonomous mobility a success.

The automotive industry is faced with difficult dilemmas, not least because it is at present primarily a physical engineering and manufacturing industry reliant on economies of scale. Manufacturers have historically earned their revenue primarily through the sale of new vehicles and associated finance packages, not from vehicles-in-use – apart from the sale of spare parts. The measure of success has been market share in new car sales. Given

the very high fixed costs of production, low prices per unit can be obtained only by high volumes. Returns are low, typically below 5%. Manufacturers have not traditionally captured the profit streams generated by cars in use; these have gone instead to franchised dealerships, independent garages, insurance companies, fuel companies and many other parties (Wells 2008). All vehicle manufacturers are now scrambling to exploit alternative business models.



Fig 49: Map showing automotive industrial centre locations & significance to the UK economy

Importance of Mobility to the UK Economy

The average household expenditure on transport is £79.70 a week, making transport the top spending category (ONS 2018). Transport is fundamentally important to the UK economy, providing employment for over 1.3 million people and nearly £40bn of GVA, but also provides a great challenge: it currently generates about 25% of UK carbon emissions, increasing to 30% by 2022 on current projections (Technology Strategy Board 2013). Cars are increasingly associated with congestion. For 2016 the economic cost of congestion in the UK was estimated at £30.8bn, with London the most congested city costing drivers more than £6 billion (Cookson 2018). Transport problems harm local economies which are unable to expand without spare capacity in local transport systems. Congestion and associated pollution contribute to low quality public space. Local firms may experience a shortage of labour because of poor transport access. For unemployed people, transport issues may be a key barrier to getting into the labour market (Campaign for Better Transport 2014). Outside cities, it has been claimed that the choices of jobs, schools, shops and leisure activities for those without cars are as limited now as two centuries ago (Metz 2014).

A Changing Landscape

New forms of mobility will produce profound changes in society including in the urban infrastructure, in the character of urban and rural life, and in health and health economics. Mobility technologies may be changing, but so are the commercial, social and cultural models with which they interact. Society must reconsider the car and its successors as elements of an integrated system, and their use as an integrated experience, using any type of transport service, public or private.

The digitally connected car (and train carriage, public service vehicle, freight truck and transport interchange) exemplifies the importance of interdisciplinary collaboration and of the changing relationship between the physical and the digital, the tangible and the virtual, and between shared and private digital information. Connected vehicles enable provision for safety, support, navigation, security, efficiency, and beyond the vehicle for automated traffic flow measurement, demand modelling, responsive road surveillance, smart roads, environment sensing, advanced toll technologies, and crowd-sourcing incident and evidence notification. These impact the individual traveller, fleet operation and infrastructure management, and create new businesses in telecoms and the creative industries: they also provide rich data for research to inform service design, physical design and policy. The interiors of vehicles and of interchanges will become information and interaction surfaces, while new services will transform the planning and making of journeys.

The transformation of cities and other places by intelligent mobility requires and enables new services, and creates new challenges

and opportunities in planning including the nature of public space, and in digital-physical integration and connectivity. These challenges require human-focused research coupled with technological innovation. Only collaborative research will be capable of tackling these issues in their material, digital and social aspects. Urban innovation is estimated to be worth over \$400 billion internationally by 2020 (Royal Borough of Greenwich n.d.). This is taking place in the context of 'Industry 4.0', with its new means of innovating, making, reusing and repairing, facilitated by digital interconnectivity and by new materials and machines. Of the 'eight great technologies' identified as UK science and technology opportunities by HM Government (Policy Exchange 2013) half intersect with the new agendas of mobility: big data, robotics and autonomous systems, advanced materials, and energy management. Of the two technologies added to the plan in 2014 (Intellectual Property Office 2014) the internet of things is also vital to the IMDC. The objective again must be 'intelligence', minimising use of energy and materials and maximising human and environmental benefits.

Transport today is unsustainable in terms of energy use, materials consumption, efficiency and cost effectiveness. Where previous university and corporate research has tended to focus on mechanics, engineering solutions to perceived problems, and iterative developments leading to incremental market advantage, it is clear now that the problem is much more subtle and complex, and requires human-centred approaches that are designed: technologies have little value if humans do not choose to use them for perceived benefit. There is an urgent need to re-focus

on the journey, the experience, the design of services and systems, the social and cultural consequences and the complexity of the infrastructure and interactions that mobility in modern advanced societies entails.

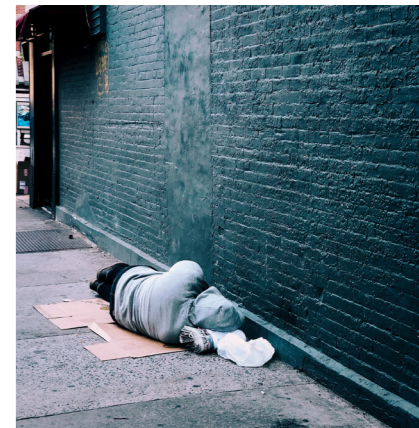
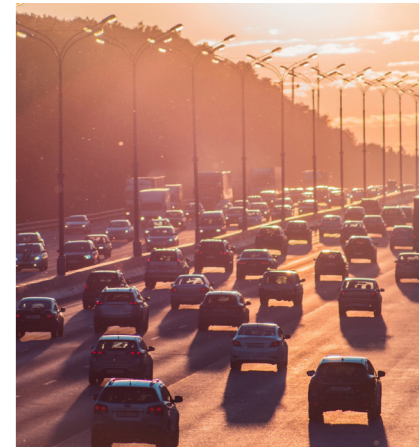


Fig 50: Challenges of mobility include pollution, congestion and inequitable access to mobility

The Role of Design

There is increasing recognition that design is one of the most important ingredients in successful organisations and the wider economy. In the view of the Engineering Employers Federation it is becoming integral to producing goods and services that enhance user experience, capture the benefits of new technologies, and differentiate businesses (Design Council 2015a). Design's contribution to the UK economy is estimated at £71.7bn, or 7.2% of UK total GVA. Workers with a design element to their work are 41% more productive than the average: each delivers £47,400 in output (GVA per worker) compared with £33,600 across the rest of the economy (Design Council 2015b). The Creative Economy has grown by a quarter since 2011, compared with growth for the whole UK economy of 12.1% (DCMS 2016). In the view of the Knowledge Transfer Network, there is a particular need for design innovators who combine depth of specialist skills with a breadth of skills crossing other disciplines (KTN 2016).

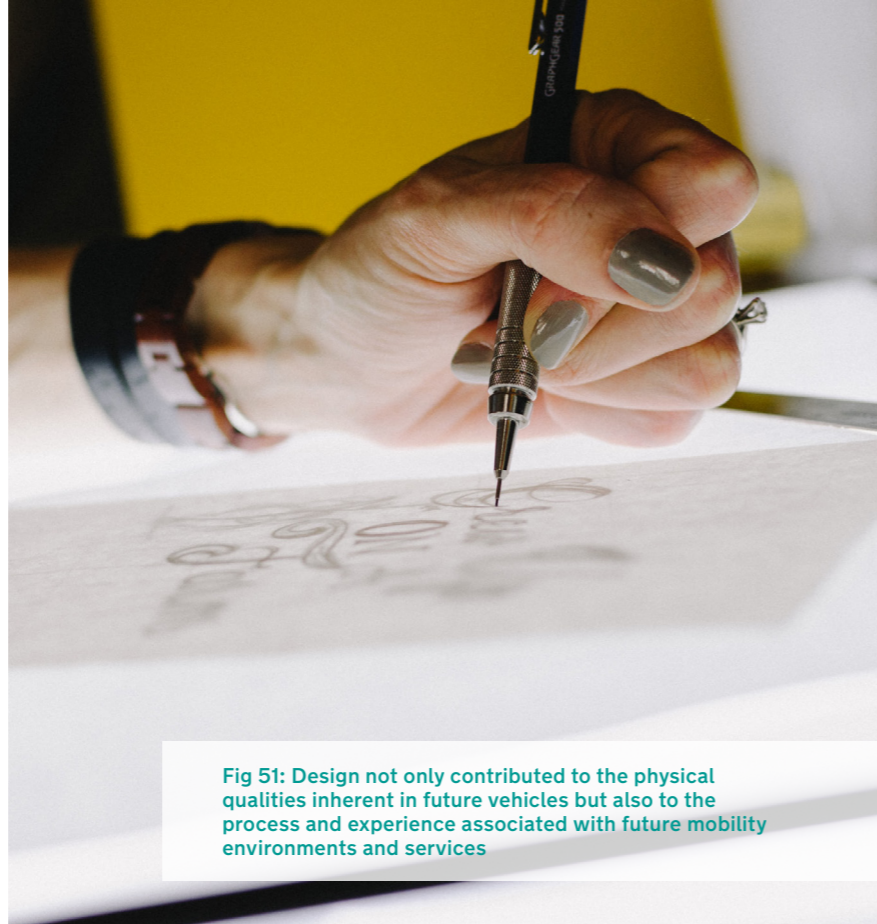


Fig 51: Design not only contributed to the physical qualities inherent in future vehicles but also to the process and experience associated with future mobility environments and services



London

The London First / London Enterprise Partnership plan for growth to 2036 calls for London to build strength in a broad set of high productivity sectors to bolster its future resilience. It identifies three core themes for London's economy: to cement its existing leadership position as a global business hub; to fuel more diverse growth through creativity and technology; and to address its weaknesses in inclusion, infrastructure and governance. London First believes that London is a world leading business and talent hub, and centre for creativity and innovation, but also makes clear that the strengths and assets that have got the capital to where it is now are not enough to maintain the city's global leadership position. It calls for swift and decisive action to address the challenges the city faces today (London First 2015). In terms of infrastructure, we have noted already the weaknesses of London's mobility provision in terms of congestion, delay and pollution. We have also shown how autonomous vehicles may enhance social inclusion – or may simply increase the already excessive traffic on the roads. In terms of London's role as a global business hub, a combination of digital expertise, digital entrepreneurship and design can contribute to the diverse growth through creativity and technology called for. London is claimed to be the third most successful tech startup location in the world, after Silicon Valley and New York, and the second most globally connected (TechNation 2018). Both digital expertise and digital entrepreneurship will be important for the mobility of the future. The UK's TMT sector (technology, media and telecoms) contributes more than 8 per cent to the country's GDP,



Fig 52: image showing landscape of the city of London

generating an annual value of £125bn. Tech and internet-related businesses contribute in excess of £60bn. London's digital industry plays a fundamental role in the British economy and has helped position London as Europe's digital capital. It has been a catalyst for growth across various industry sectors (London's Digital Industry n.d.). Citymapper, originated in the UK and originally designed for London but now available for forty cities worldwide, has attracted \$50m inward investment, and is made possible by the open data policies of the cities where it operates. Design-led approaches to autonomous vehicles, intelligent mobility, and mobility services and experiences more generally exemplify the productive combination of technology and creativity. Such approaches would help to solve London's infrastructural problems in relation to transport and mobility, including empowering excluded communities, while addressing the city's identified weakness that its ideas and early-stage entrepreneurship are currently only modestly translated into strong business growth.

8.2 Future Research

Increasing the Reach of Mobility

Mobility is a resource that is differentially accessed (Cresswell 2010). Autonomous vehicles have significant potential to offer mobility to those whose access is currently restricted. One core group in this category are those too young to be allowed to drive. Other key groups are those made less able to drive by age or disability, often with concomitant low economic status: these groups often also have limited options – or none at all – in public transport. Whereas at one time society seemed to regard this as just the inevitable result of age or disability, increasingly the rights of such groups to mobility are rightly recognised and asserted. The Universal Declaration of Human Rights actually includes a right to mobility: Article 13 states that everyone has the right to freedom of movement and residence within the borders of their state (and the right to leave and return). This is often taken to refer to political prohibitions on movement, but could just as well be considered a practical right within society. Mobility is a crucial component of personal independence, with implications not only for economic and social freedom but also for well-being and self-worth. Practical issues are bound up with political and societal questions. A report for the Joseph Rowntree Foundation states: “In order to experience equal access to full citizenship, disabled people require some kind of collective and redistributive mechanism. Such redistribution needs to be in the context of a value system which values diversity and in which disabled people are treated as belonging and contributing to the communities in which they live. There is little

room for making progress within the ideological framework driving current [UK] disability policies” (Morris 2011). Mapping these ambitions to our PESTEL analysis presented in Chapter 6, there is hardly any category omitted by the need for increasing access to mobility: it is a political question given the need for leadership at the highest political levels, championing a new ‘ideological framework’, and in terms of the need to empower neglected groups with control over their own futures; it is economic, in terms of its cost implications, but more importantly in terms of enabling more people to be active and productive participants in society; it is a social issue, both in terms of increasing social inclusion and in terms of changing attitudes; there are measures to be taken that are technological from the detailed ‘touch-points’ through which people access services through to the design of systems and services themselves; it is a legal question, given the need for significant legislation to, for example, force transport providers to consider the needs of all users; It is environmental because the poorest and least able often face the brunt of environmental pollution, while the youngest and unborn generations will be faced with the heaviest burden from the climate crisis.

As we have done within GATEway, it is essential that research is undertaken with, and not just for, currently disadvantaged groups. Wider access to mobility calls for research and design interventions at every level from the design of vehicles, to that of the tools with which people interact with systems, the places and means by which they are accessed, up to the strategies and policies of manufacturers, human interaction specialists, transport providers, transport authorities, local and national governments and strategic bodies such as the Catapults.



Fig 53: Eleanor Roosevelt holding the English language version of the Universal Declaration of Human Rights

New Mobilities, New Capabilities

What new possibilities are opened up by driverless cars, and autonomous vehicles more generally? We have discussed in this report a number of visions of the future, including a variety of new liberations within the vehicle itself such as the mobile office, mobile medical treatment space, mobile leisure opportunity, or simple reconfigurations such as abandoning forward-facing seats for seats that face one another (as they have done for years for example in the passenger compartment of traditional London taxicabs) so affording greater social interaction and perhaps more productive journeys. Against that vision we have also cited the widespread findings that people are not easily attracted to the idea of sharing their transport with strangers without the anonymity provided by the crowds in a bus or a railway carriage.

A key design concept here is that of affordance, introduced into behavioural psychology and the science of perception in the 1960s by Gibson (1966), and widely adopted in human-computer interaction and experience design as a result of its adaptation to those fields by Norman (1988). Affordances are the properties of an object or a system that suggest the possible functions it may perform and how users may interact with or exploit it. A standard example is a cup, whose handle suggests grasping and whose hollow interior suggests use as a container. Notoriously, designed artefacts and systems may afford interpretations and actions that their designers did not foresee (Gaver et al. 2007); there is also historic evidence of our inability to successfully imagine how the technologies we design will be used (e.g. Marvin 1988). What may be the affordances of new designs

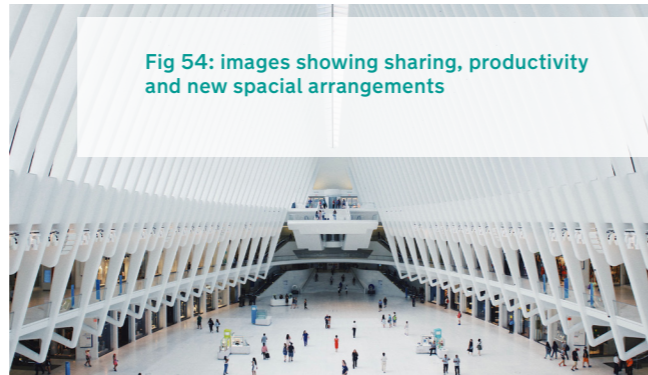
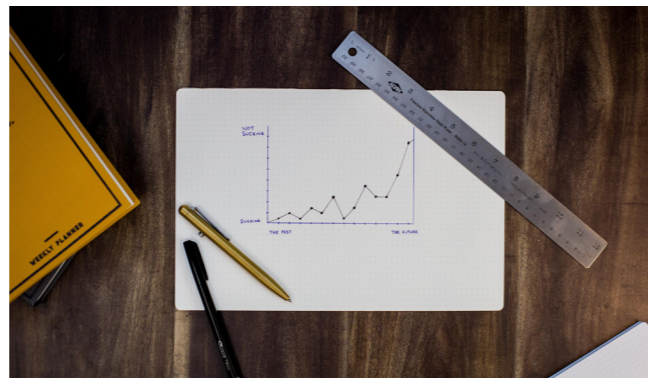


Fig 54: images showing sharing, productivity and new spatial arrangements



of vehicles and the systems they inhabit? We can almost guarantee that their uses will not match those predicted. This difficulty is aggravated by the kinds of wicked problems discussed in Chapter 6, such as the way that fixing one problem may create another, that solutions have to be developed before the problem is fully understood, that even then when they are we don't necessarily know if we have 'solved' the problem, that wicked problems have no straightforwardly alternative solution. As discussed in Chapter 6, determining the 'best' solutions is confounded by competing priorities. Earlier we discussed the 'need' for the UK's automotive manufacturing industries to survive and grow – but does this conflict with the objective to dramatically reduce the number of cars made, instead optimising their use through sharing, and so minimising materials use, manufacturing, and expensive recycling?

If the future of autonomous vehicles is so unpredictable, conflicted and filled with wicked problems, what kinds of research can be done? As discussed in Chapter 7, design has a crucial contribution to make because of its ability to iteratively prototype and test tentative future solutions – often in surprisingly inexpensive and low-fidelity ways. Such tentative modelling does not perform a separate function from the research – it is a vital part of the research methods in its own right. Designers usually have a well-developed ability to empathise with imagined users, which of course can be further enhanced by working closely with users throughout the design process. This includes post-implementation studies, where we learn from how artefacts and systems are really used, and how those uses change, ideally over many years.

WORRIES CONCERNS
Draw or write your hopes and dreams for a driverless future:



Fig 55: Image showing a card from the GATEway exhibition

Dystopia

We also discussed in Chapter 7 our perhaps surprising embrace of dystopian views of some driverless futures. The task of the GATEway project was to respond to the original call from Innovate UK (then the Technology Strategy Board) who had said that they would invest up to £10m in collaborative R&D projects to 'research further how driverless cars can be integrated into everyday life in the UK.' The objective was further defined as 'proving how driverless vehicles will be integrated in a real-world environment' (Technology Strategy Board 2014). This was not therefore primarily a call for research on whether driverless cars could be integrated into our lives, but how they could. Nevertheless we decided that it was essential to look not only at people's aspirations and hopes, their approval for autonomous vehicles, but also at their anxieties, their fears, their objections. If 'the purpose of GATEway is to understand how these technologies will fit into society' (Reed

2017), it was essential to look at how such technologies might not fit.

Mullins emphasises the crucial relationship between innovation and society: ‘Technical and service innovations have the power to be both beneficial and disruptive to the city. Innovation repeatedly poses the question of what kind of place we want to create for the future’ (Mullins 2017). As Dunne and Raby (quoted in Chapter 7) have said, ‘design’s inbuilt optimism can greatly complicate things, first, as a form of denial that the problems we face are more serious than they appear, and second, by channelling energy and resources into fiddling with the world out there rather than the ideas and attitudes inside our heads that shape the world out there’ (Dunne and Raby 2013). Rather than taking the world as given and some futures as inevitable, designs may instead attempt to take nothing for granted. If artefacts, technologies and systems can shape our thinking and behaviours, alter society, and perhaps even alter our perceptions, then the futures they may create must be investigated for both good and ill.

As we noted in Chapter 7, an exhibition may not simply be a method of dissemination. It is also a powerful means to engage with a range of publics, to provoke debate, and to create new knowledge through the interactions afforded to visitors. Thirty thousand visitors came to the Driverless Futures: Utopia or Dystopia? exhibition at the London Transport Museum in Spring 2017, where we elicited over 1,500 pieces of feedback. A debate was held at the venue, public workshops took place over two months, and the programme ended in an expert panel. The insights gained fed back into our ongoing design research.

A wide spectrum of tactics is called for to engage a range of publics, from mass numbers to tiny groups, using techniques that empower future users to identify their hope and fears, aspirations and concerns, and, wherever possible, to address them imaginatively together. These forms of research are essentially productive, as well as diagnostic – they help to produce solutions.

Key Disciplines for Future Research

How things are perceived – through sight, sound, touch and other senses – is a vital element of their success or failure. But design comprises far more than just aesthetics, and often is at its most productive in multidisciplinary collaborations. Design engineering for example brings together engineering knowledge such as manufacturing techniques, materials science, mechanics and ergonomics in a creative design context. Intelligent mobility and integrated transport are emerging as disciplines in their own right, beyond traditional transport studies, bringing social science, service design, software engineering and other disciplines into the mix to address the challenges of user-centricity, integration, efficiency and sustainability. An understanding of HCI – human-computer interaction – is essential to many aspects of autonomous mobility, from new kinds of information and communication services within vehicles, to apps for finding and hailing services. At one time confined to interactions with clearly identifiable computers, HCI now deals in a multisensory way with all aspects of embedded computation using devices and interaction surfaces of all kinds. Service design meanwhile has much to offer through its inherently integrated approach to the

design of human experiences and the socio-cultural, economic and technological systems in which the services are experienced. Service designers aim to integrate multiple design disciplines to create a systems-based solution that resolves the often complex needs of many different stakeholders in addition to the human experience of receiving or delivering a service. Calling on a wide range of technical, design and management skills, service design seeks ways to deliver ‘value’ (and to define what that value is) for every actor within a system.

As already stated, we wish to deliver profound social benefits as well as commercial and strategic gains, to enable key industries and institutions to rethink their role and identity, as digital technologies change the nature of the world they deal with, and to rethink existing practices as human-focused services. Nowhere is this more necessary than in designing a future for driverless cars and other aspects of autonomous mobility.

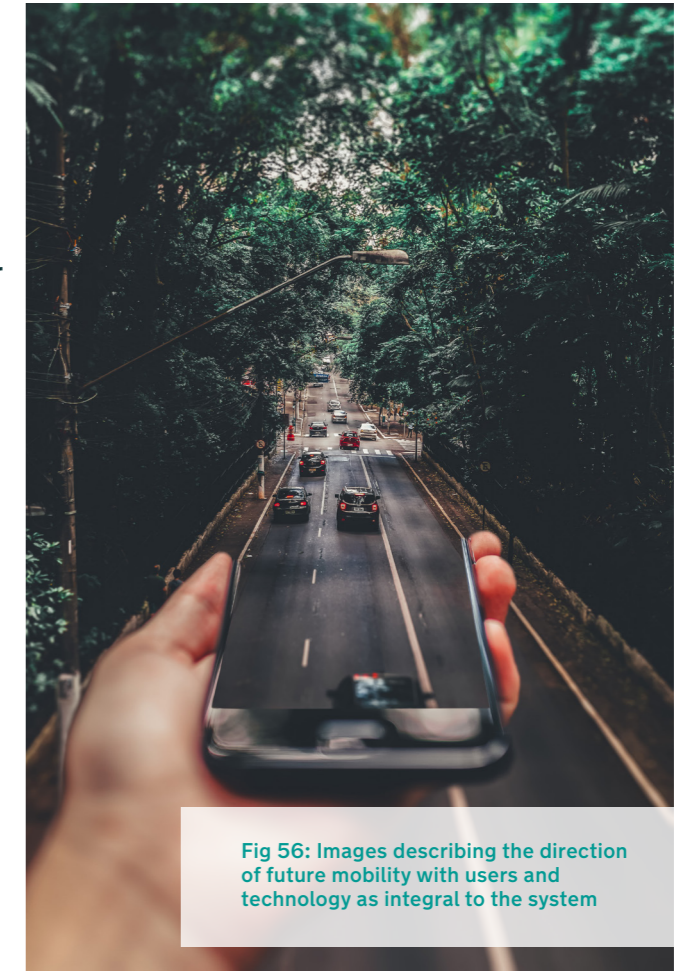


Fig 56: Images describing the direction of future mobility with users and technology as integral to the system

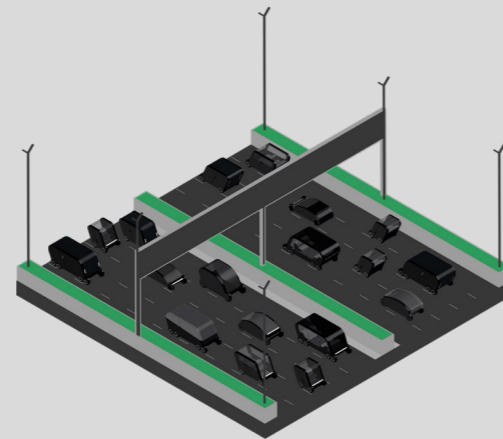
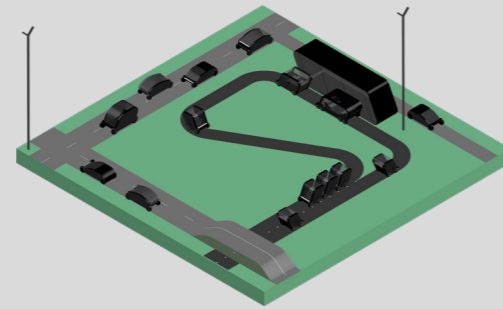
8.3 Implications

We see this report as the starting point for deeper design research which looks in more detail at specific community needs, urban environments and vertical markets as well as more focussed research around vehicle typologies, interior environments and communication systems.

At an individual level, design can be used to create more inclusive interfaces and show how they will work and be experienced through both digital and physical interactions; it can show how shared interior environments can become more flexible, more comfortable and more useful; and it can help to create more seamless journeys that support healthy lifestyles and improve the experience at modal interchanges.

At the community level, design can be used to re-imagine streets, parking and vehicle infrastructure, showing how automation can be used to improve the urban experience while also reducing the cost and impact of new technologies.

For society as a whole, automation and Artificial intelligence will have a growing impact on our environments, products and services. Design can be used to help industry and the public steer away from the more mundane 'probable future' and the potentially dystopian 'possible futures' to a preferable future that meets our needs and aspirations in an inclusive and humane way. Automation needs to be designed with and for people, rather than people designed for automation.



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Acknowledgements

The GATEway project is joint-funded by government and industry. It has received £5.5 million in funding from the Department for Transport (DfT) and the Department for Business, Innovation & Skills (BIS) through Innovate UK and is supported by the Centre for Connected and Autonomous Vehicles (CCAV), which is the UK government policy unit set up to drive the governments activity on connected and autonomous vehicles. This funding is supported by an additional £2.5 million from the commercial organisations within the GATEway consortium.

We would like to thank our project partners and collaborators with a particular thanks to the experts who took part in our research activities and supported the development of this publication through a series of expert panels. These included:

Ben Dodds	Digital Greenwich
Elizabeth Box	RAC Foundation
Francesc Aragall	Design for All
Iain Macbeth	Norge
James Bonner	Transport for London
Kristen Fernandez	O2
Onny Eikhaug	TRL
Rebecca Ashton	Design og Arkitektur
Simon Tong	IAM Road Smart
Theo Quick	TRL
	ATOS



Fig 49: Future vehicle interiors may be more useful and playful. Here, researcher Paul Piliste, imagines a future family vehicle complete with ball pit and holographic interfaces. Kids play while their mum reads and has a drink

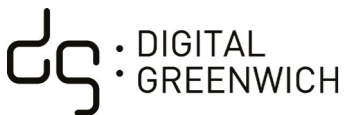
Project Partners

TRL

The projects lead and research partner. TRL has been working on automated vehicles for more than 50 years.



The local authority and smart city partner, providing the venue for the trial and looking at the wider implications for city authorities.



Facilitating the Greenwich trials and local stakeholder engagement. It will also be looking at the interdependencies between connected and autonomous vehicles, the design of the built environment, smart mobility services and the role of cities in accelerating take-up.



RSA (Royal Sun Alliance) Working to understand how automated vehicles might disrupt the motor insurance market and will support the risk mitigation strategy.



Shell. Focused on understanding how automated vehicles will impact its existing business models.



Focused on understanding the networking implications of automated vehicles and the impact they will have on its business and consumers connectivity needs.



UNIVERSITY of GREENWICH

Undertaking research to extend its world-renowned pedestrian modelling capability to consider interactions with automated vehicles.

Imperial College London

Considering the cyber security implications of the specific trials and wider implementation of connected, automated vehicles.



Royal College of Art

Drawing on its internationally recognised expertise in stakeholder engagement in relation to vehicle design to provide detailed insights into stakeholder attitudes to vehicle automation.



Commonplace

Providing innovative sentiment mapping techniques that analyse social media to measure users' response to experience of automated vehicles. Residents and visitors to Greenwich Peninsula are invited to leave feedback of their experiences and observations of interacting with the driverless shuttles via an interactive map.



Delivering the demonstrations of vehicle teleoperation and support to the automated vehicle trials.



Westfield Sports Cars Responsible for the procurement and build of the shuttle vehicles and overall systems integration.

Heathrow

Making every journey better

Responsible for the design, testing and engineering of the GATEway shuttle vehicles and their control software.

OXBOTICA

robotics & autonomous systems

Developing the sensor technology and software to support the safe operation of the shuttle vehicles.



Driverless Futures

Design for acceptance and adoption in urban environments

This report, from the Royal College of Art's Intelligent Mobility Design Centre and the Helen Hamlyn Centre for Design, shows how people-centred design research, carried out as part of the GATEway project in Greenwich, London, can be used to understand people's needs and aspirations and create design proposals that use this knowledge to increase the acceptance and adoption of driverless vehicles in an urban environment.

Through this work we show how future public, private and shared driverless vehicles can be designed to meet the needs of different people while also contributing to improved urban environments that are safer, cleaner and more inclusive.



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We work with

Innovate UK