Cities for Driverless Vehicles

**Planning the future built environment with
shared mobility**

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Planning the future built environment with shared mobility

Edited by

Xu Zhang

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Preface

Movement is life. From flying horses to magic carpets, the desire for effortless movement and the associated freedom have long been ingrained in human culture. Not long after Ford rolled out the surface-bound Model T car, affordable to ordinary families, in 1908, the Futurama exhibition of 1939 unveiled, alongside an accompanying vision of cities and countryside, a self-driving concept car from General Motors. A more recent landmark event followed in the form of a race in the pursuit of workable autonomous vehicles, initiated by the Defense Advanced Research Projects Agency (DARPA) Grand Challenge in 2004. Five years later, in 2009, the spotlight shone brighter on self-driving autonomous cars after Waymo, the Google spin-off, started its self-driving car project and subsequent road tests. Self-driving vehicles have since received intensive attention from policymakers, business, academia and the general public. Tremendous progress has been made in the technology, shown in numerous test trials and pilot services worldwide. Attracted by the projected benign and liberating prospects of driverless vehicles and the prospect of a new powerful driver to spur economic growth coupled with faith in technological advances, a sense of the inevitability of its materialisation, real or illusory, is at times almost palpable.

What does this mean for the way we live? Thus far, there has been limited scrutiny of how this technology will fundamentally impact the cities that will be its host. What will these future cities of driverless vehicles look like? Can what is expected, for example, a dramatic reduction in accidents and congestion relief, be realised as anticipated and desired? If the hopes and dreams of this technology as portrayed by its promoters are to be turned into desirable realities, they must be prudently analysed and clearly decoded.

Technology development driven by the market has by far been the main focus in the public discourse on the driverless future. The involvement of city planners, designers, engineers, architects, sociologists and the public is conspicuously lacking. Technology is important and its development has played a critical role in the past in the evolution of societies, in shaping the human habitat and, consequently, the planet. The impacts of changing mobility technologies, from bare feet, to horses and carts, to railways and ships and then to cars and aeroplanes, can be clearly felt in contemporary cities and their histories. While car-dominated mobility has brought with it an unprecedented range of choices and prosperity, it has also

cursed us with fragmented cities fraught with unintended consequences. Congestion, pollution, noise, dirt, fumes, threats to life and limb are the most immediately observable, yet wider-reaching social, environmental and ecological repercussions too loom over us. Today, we are facing major challenges of global warming; rapidly degrading ecosystems, diminishing biodiversity and depleting natural resources; increasingly frequent and more severe flooding, heat waves, hurricanes and other extreme weather events and rising social divide and tension. The construction of future transport systems, which underpin the form and structure of cities and lifestyles, has a critical role to play in meeting these challenges.

At the cusp of this new frontier in the way people and goods move, it is crucial to reflect on the question of what kinds of city can cohabitate well with the technology in order to bring benefit to the individual, society and the planet? There should be no doubt that the vehicles we design and manufacture are for supporting life, and not the other way around, a painful realisation after a long history of car-dominated city planning and design. This brings another set of questions: what are our lifestyle and societal aspirations? How, and in what way, can driverless vehicles support these? Can they help to lessen or, better still, put an end to rather than exacerbate the ills brought by the past mass deployment of cars and vehicles? This book gathers the thoughts of leading scholars and practitioners in urban and transport planning and design worldwide on this exciting development.

Rather than starting from the technology and modifying our environment in order to best utilise it, in other words, letting the technology impose changes on our lifestyle, this book starts from lifestyle and societal aspirations, and planetary requirements, to understand how the technologies could fit and adapt and be adopted in the most beneficial ways.

Starting from people, and society and planet, will inevitably bring different views about futures, with different value systems, as well as varied assessments of uncertainties in technology development and adoption path. These differences were discussed in a series of debates among the authors leading up to the publication of this book. Rather than seeing these differences as an inability to reach a consensus and to find a solution, we regard them as a part of the nature of city building that should be positively welcomed. This is reflected in the

book. After all, city building is society building; it is first and foremost a social activity. It is an implicit design process, although in the short term it is often seen, or preferred to be seen, and interpreted as a deterministic and scientific exercise to discover the optimal solution. But cities are living organisms. Their long-term optima are illusive, if they can be formulated at all, as many of the problems we face are wicked problems. Underlying values of judgement are often subject to change and may not even be apprehended, and their impacts and outcomes may not be foreseen or valued at any particular point in time. It is a design process of finding what is possible and what is desirable in a way that reflects the whole spectrum of society. Achieving a consensus while respecting differences is how we may prepare for the probable and drive for the desirable.

This book is mostly focused on cities, where the most complex transport and social problems occur. The addition of autonomous vehicles (AVs) and the evolving mobility as a service (MaaS) to the planning toolset will give planners and designers much needed power and flexibility, not only to introduce diversity and variety to cities to match the different aspirations of their citizens, but also to make cities more dynamic, inclusive, multifaceted and liveable.

At a time of potentially disruptive change, the mobilising and garnering of collective wisdom is crucial. Hence, rather than trying to seek a definitive single best view of the future, this book aims to contribute to a healthy debate, both in shaping and designing future cities and their transport systems, in which driverless vehicles can be meshed in seamlessly, and in developing and refining the technical and social tools for achieving this goal.

I am truly honoured to have gathered a spectrum of distinguished scholars and practitioners, all of whom are highly regarded in their respective fields, to present their views. I am also humbled to read their insightful and inspiring work. I hope this book can provoke your thoughts and inspire your work in searching and providing solutions towards building better cities.

This book was initiated by an invitation from James Hobbs of ICE Publishing. I am deeply indebted to the support provided throughout from conception to delivery.

Xu Zhang

About the editor

Xu Zhang is a (part-time) professor at the School of Civil Engineering and Architecture of the Henan University of Technology, China, and an independent transport planning consultant based in London, UK. Xu is also a visiting professor at the School of Traffic and Transportation at Beijing Jiaotong University. He sits on the editorial panel for the international journal *Proceedings of the Institution of Civil Engineers – Municipal Engineer* and is an editor for the *International Journal of Transportation*.

Xu has trained in transport, computing and electronics sciences and holds a PhD in transport studies from University College London, an MSc in computer science and a BSc in electrical and electronic engineering, the latter two from the University of Science and Technology of China (USTC). He has held senior roles in a number of transport planning consultancies and academic institutions, acting, in consultancies, as associate director in transport planning at Halcrow Group Ltd, associate at Colin Buchanan and Partners and chief expert at the intelligent transport systems (ITS) firm Anhui Keli Information Industry Co. Ltd. Academically, he served as British Royal Society guest research fellow at the Artificial Intelligence Department of the University of Edinburgh, external MSc course lecturer at the University of Surrey and lecturer at the Information Technology Research Centre of the USTC.

Over the past 30 years, Xu has undertaken consulting, research and teaching assignments in transport planning and design, transport modelling and analysis, traffic management and controls geographic information systems (GIS) and urban traffic control (UTC) systems worldwide in countries of different cultures and development paths. Apart from the UK, he has been a resident transport planner in China and the Middle East and consulted in many cities, immersing himself in the aspirations and practices of local communities and experts and producing convincing solutions. His work is underpinned by a mastery of a spectrum of technologies in computing, system development, artificial intelligence (AI) and data analytics. These have given him a unique viewpoint in appreciating the dynamics between communities, transport and technologies and in contemplating cities of a driverless, smart and sustainable future.

About the contributors

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Matthew Cockburn is a Transport Development Management Coordinator at Bristol City Council, UK. In his role, Matthew assesses the future transport impacts of proposed new developments to ensure that they are compatible with national and local transport policy. He was previously a Project Manager in the City Innovation team at Bristol City Council, where he worked to explore, develop and test how new technologies can be used to improve the functioning of the city. Matthew has worked on two high-profile driverless car projects: Flourish and Venturer. Working as part of multidisciplinary teams including universities and leading technology companies, he explored how these technologies will change how people move around cities and how much residents will accept the roll-out of driverless technologies. Matthew also worked on a high-profile smart city project, Replicate, which is investigating how new technologies in the fields of mobility, energy and ICT will be rolled out in cities.

Koji Hachiyama MEng, is Chief Operating Officer, ERIA (Economic Research Institute for ASEAN and East Asia). After graduating with bachelor's and master's degrees in engineering from the Tokyo Institute of

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Dale Harrow is Chair of the Intelligent Mobility Design Centre (IMDC) at the Royal College of Art (RCA) and Head of the Intelligent Mobility Design Programme, recognised as a global centre of excellence in automotive and design education. As the inaugural Dean of the

School of Design at the RCA, he reconfigured the school, introduced new programmes in service design and international programmes in innovation design and championed multidisciplinary design methods through new curriculum development and design projects. He is a multi-award-winning designer, academic leader and researcher and is regularly cited as one of the most influential and important figures in the automotive industry. He is committed to design education and is always keen to raise the intellectual debate about automotive and mobility design. Professor Harrow's approach to the discipline reflects his belief that it is a complex subject, constantly moving forward, and that designers have to innovate and be better informed to meet current and future challenges. His work has initiated new transdisciplinary methods and approaches and explores broader and emerging issues, such as the changing city, technology and new commercial opportunities to develop innovative design solutions within an established and evolving design culture.

Jacobs Cities Solutions comprises Carlo Castelli, Vaggy Georgali, Javier Inigo, Maria Kouridou, Conor Morris, Helen Ng, Esmee Stalenberg, George Wade and Mary-Jane Wood. The Cities Solutions team at Jacobs is structured around a holistic approach to city making and urban design, always open to new interpretations and creative processes. Their methodology sets out an iterative process, by which continuous engagement and collaboration are encouraged. This allows all participants to contribute to an agreed set of principles and objectives, as well as maximising the impact of potential interventions. The team is made up of specialists in the fields of planning and design with expertise in city design, engagement and research. Their skills have allowed them to work on a broad range of projects, from regional planning in the Middle East to research on social inclusion, incorporating city strategy, master planning and architecture programming. Their style varies as they see every task as an open opportunity to question themselves and the business-as-usual approach. That being said, benchmarking exercises and good city practices are at the centre of their methodology. One of their focus areas is sustainable mobility and integrated transport. Their approach to mobility and transport aspires to be multifaceted; with overarching themes of 'people-focused and data-driven' at the heart of their projects, from city-scale to territories and regions, enabling a strong level of integration and interrelation

between current emerging trends and city making. As a team, they are particularly interested in the social and physical parameters that shape our everyday urban environments and they are always curious to speculate, imagine and illustrate the spatial implications of unprecedented phenomena. Technological, economic, social and climate-related challenges offer a window of opportunity to truly imagine and work collaboratively towards resilient, human-centred cities and places. They use a wide range of tools to communicate their ideas, from technical to more conceptual diagrams and physical props. Their inspiration comes from their mix of different backgrounds and experiences, their everyday environments and, of course, the cities they visit, explore, live in and watch on screens or read about in books. Their contribution to this publication has been seen as an opportunity to reflect on how the urban form will be affected by CAVs through the eyes of urban practitioners, and also city dwellers. They set themselves the challenge of speculating over less and more probable urban futures. Their approach leans more towards fiction and some of their words are turned into illustration to pose more persistent questions about our future cities.

Peter Jones OBE is Professor of Transport and Sustainable Development in the Centre for Transport Studies at University College London (UCL); he was previously Director of the Transport Studies Group at the University of Westminster. His main areas of expertise include urban and national transport policy and planning, traveller attitudes and behaviour, and sustainable lifestyles. He has contributed to many advances in transport methods over a wide range of areas, including qualitative and quantitative methods of data collection and analysis, stakeholder engagement, modelling and forecasting, and appraisal and evaluation. He leads a major EU project (MORE – Multi-modal Optimisation for Road-space in Europe), looking at current and future pressures on road-space in urban areas, and is coinvestigator for a UK ESRC project on ‘Debating driverless futures: anticipatory governance and responsible innovation for self-driving cars’. He is a member of the Department for Transport (DfT) Science Advisory Council, cochairing its Joint Analysis Development Panel, and is a Commissioner on the Independent Transport Commission. He is a member of the Daimler Advisory Board for Integrity and Corporate Responsibility; he sits on the Dubai Future Council for Transportation and on the Hong Kong International

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engineering in 2017 from Zhengzhou University, China. Her research has mainly focused on urban road network planning and design, road functions and network hierarchy, in support of sustainable urban development.

John McCarthy PhD is the Global Lead for Shared, Connected and Autonomous Vehicles and European Business Lead for Intelligent Mobility at Arup. John is particularly interested in how customer-centric services can be created in a fair and equitable fashion within the constraints of how we operate today and how we wish to operate in the future. John has delivered a number of MaaS- and CAV-based projects in the past and was a House of Lords expert witness for CAVs. John has directed a number of high-profile Autonomous and Connected projects across the globe and has acted as supervisor and reviewer of several research projects. John has a PhD in electrical engineering from Trinity College Dublin.

Jonathon Murphy is Public Affairs Manager at AXA UK. Jonathon is part of AXA UK's Public Affairs team, which manages AXA UK's relationship with political stakeholders in government and parliament. As an in-house Public Affairs specialist at a leading UK insurer, Jonathon works on a vast range of industry issues, running campaigns and developing policy in areas including transport, flooding, building safety and private healthcare. AXA UK has been involved in connected and automated mobility since 2014 and is a partner of five UK government-funded consortia (Venturer, UK Autodrive, Flourish, Capri, Robopilot), developing and trialling CAVs. AXA UK's role in these consortia is to provide advice on safety, regulation, liability and data, and the provision of insurance for some trials.

Graham Parkhurst MSc PhD FRGS is Professor of Sustainable Mobility and Director of the Centre for Transport & Society, University of the West of England, Bristol. Graham holds degrees in psychology (BA, University of Warwick), biological anthropology (MSc, University of Oxford) and transport geography (PhD, University of Oxford), and has undertaken research and taught academic transport and mobility studies since 1991. Past research interests include urban and subregional transport policy, modal interchange policy, air quality policy, mobility of the ageing population, transport policy instruments and the evaluation of urban transport policy implementations (specific infrastructure interventions, mobility services

and vehicle technologies). His current research involves examining the wider implications of trends to greater automation, electrification, flexibility and the use of digital technologies in the transport sector, taking a critical lens to the discourse and practices of ‘smart mobility’ and ‘smart cities’, through projects such as *Driverless Futures?* (Economic and Social Research Council). Graham has provided social and behavioural research contributions in respect of UK government-funded (Innovate UK) research consortia examining connected and automated vehicles (*Venturer*, *Flourish*, *CAPRI*, *MultiCAV*, *CAVForth*) and flexible collective transport solutions (*Mobility on Demand Laboratory Environment*). Electric mobility is the focus of a European Commission-funded project (*Replicate*), which seeks to pilot and ‘upscale’ electric car and cycle sharing. Graham also teaches Transport Policy at Masters’ level and is a Fellow of the Royal Geographical Society.

John Parkin MSc PhD CEng FICE is Professor of Transport Engineering at the University of the West of England, Bristol. He began his career in highway and traffic engineering with consulting engineers, and has been involved in all stages of the promotion of transport schemes, including policy formulation, modelling and forecasting, operational analysis, economic appraisal, design and construction, and monitoring and evaluation. He has experience across all land-based modes of transport and his research has included modelling, empirical traffic engineering research, and monitoring and evaluation. He has authored a book, *Designing for Cycle Traffic: International Principles and Practice*, published by ICE Publishing.

Giles Perkins leads WSP’s future mobility team in the UK and has 30 years’ experience in the transportation planning and intelligent transport sectors. He has worked in the public and private sectors as a senior client and director level consultant, leading major projects across all modes. He has a detailed understanding of the strategic needs and opportunities surrounding the transport challenges that face our networks, regions, towns and cities. Giles is a recognised expert in the field of future mobility, access and transport, having undertaken numerous cutting-edge commissions where his insight is helping build ‘future-ready’ thinking into strategies, policies and asset specifications. He is a strategic thinker with an in-depth appreciation of the challenges facing all modes of transport resulting from disruptors, both within the transportation realm and wider socioeconomic

changes that influence it. Giles has presented papers at numerous events and conferences in the UK, Europe, Japan and Australia, focusing on the potential challenges and opportunities in the new or future mobility space, particularly on how we can navigate uncertainty. Giles was a key contributor to WSP's well-received publication *New Mobility Now*; he contributes to their ongoing international research programme and contributed to the Go Science and DfT roundtables on Future Mobility.

Peter Ramsey jointly leads WSP's future mobility capability in the north of England and Scotland and has over 20 years' wide-ranging experience in transport planning and future mobility. While focusing on the transport discipline, he is a chartered town planner and has spent his career bringing together thinking on place and movement. His experience in leading projects as a consultant working across the public sector has primarily focused on developing policy and strategy for local, regional and national clients. His experience as a project manager and director covers strategic and local policy, business case development, concept and feasibility studies, route management and sustainable travel.

John Siraut is Director of Economics and the Global Technology Lead for Transport Economics at Jacobs in London. He is presently chair of the Transport Economics, Finance and Appraisal Committee of the European Transport Conference. John specialises in the wider economic and social impact of transport, as well as advising on more general economic development issues. He has advised on all modes of transport and most of the UK's largest infrastructure projects, including Highways England Smart Motorway Programme and all phases of High Speed 2. He has acted as expert witness at public inquiries and examination in public on transport, retail, employment and economic issues, and has acted as adviser to transport and finance scrutiny committees. John is the author of over 70 articles, has given TV and radio interviews on a range of topics and is a regular speaker at conferences in the UK and overseas and increasingly online. He previously worked for HM Treasury, the Home Office and Ernst & Young.

Rachel Skinner is Executive Director for Transport at WSP, a Fellow of the Royal Academy of Engineering and an Honorary Fellow of the Society for the Environment. She is currently serving as ICE President to November 2021, with a focus on climate action towards net zero carbon. Between 2018 and 2020, Rachel was appointed by

the Scottish Government as a Commissioner for the Infrastructure Commission for Scotland and she is a patron of not-for-profit Women in Transport, having been one of its founding board members since 2005. She is a chartered engineer, chartered transport planner and an ICE Fellow and Trustee. Rachel is a regular keynote speaker at national and international events, talking regularly on the topics of net zero carbon and future mobility. She has also co-authored two pioneering white papers on future mobility, *New Mobility Now* (2017), on emerging market trends, and *Making Better Places* (2016), on place-led foresight and specifically the new placemaking potential that could be enabled by automated and connected vehicles over the decades to come. Named as one of *The Telegraph's* inaugural top 50 influential women in engineering in 2016 and declared both 'most distinguished winner' and 'best woman in civil engineering' at the European Women in Construction and Engineering Awards in 2017, Rachel was confirmed in 2019 by the *Financial Times* as one of the UK's Top 100 women in engineering.

Paul Speirs is Senior Director and Global Head of Pre-Sales at PTV Group. Paul has 27 years' experience in developing transport modelling solutions. After studying at Edinburgh Napier University, Paul completed the hard miles of learning the modelling trade with Surrey County Council, Atkins and WSP. For the last 6 years, Paul has been engaged at the pioneering end of PTV's modelling solutions, particularly in the field of shared mobility, where his practical experience and influence helped shape PTV's mobility solutions portfolio. Paul has delivered shared mobility proofs of concept and projects around the world, including in Japan, the USA, the Middle East and across Europe, working in collaboration with original equipment manufacturers (OEMs), public transport agencies and consultancy partners. His work is captured in the 2019 publication of *The Oslo Study – How Autonomous Cars May Change Transport in Cities*. Paul's motivation is to simplify the world of transport modelling through engaging and well-articulated story telling that allows clients and stakeholders to fully comprehend prepared evidence without getting bogged down by the sometimes baffling complexities. Even in forecasting uncertainties, such as emerging mobility trends, providing pragmatism in application can go a long way to simplifying what can be a complex world.

Luis Willumsen has over 35 years of experience as a consultant, transport modeller and planner. He is

coauthor of *Modelling Transport*, a book published by Wiley, now in its fourth edition and translated into Spanish and Italian. He has also published *Better Traffic and Revenue Forecasting*, dealing with the critical task of delivering demand and revenue projections for transport concessions. He is Director of Willumsen Advisory Services and of Nommon Solutions and Technologies, a company specialising in the use of smartcard and mobile phone data to deliver useful transport insights. Through both companies, he has focused on the future impact of new mobility, the use of big data in modelling and managing uncertainty and risk. He is also Visiting Professor in the Department of Civil, Environmental and Geomatic Engineering at University College London.

Brian Wong is a Director in the Transport Sector group within UK law firm Burges Salmon LLP, UK. Brian chairs Burges Salmon's Transport Technology and Intelligent Mobility (TTIM) group. In particular, he coordinates and leads on thought leadership on the legal and regulatory implications of CAVs, liaising extensively with the UK's Centre for Connected and Autonomous Vehicles, Zenzie, British Standards Institute and the Law Commissions. He has coordinated the firm's partner involvement in five Innovate-funded CAV projects since 2014: Venturer, Flourish, Capri, RoboPilot and MultiCAV, looking at CAV regulatory issues across a wide range of use cases, covering road vehicles, pods, commercial vehicles and passenger transport. He and the Burges Salmon team have advised and authored extensively on CAV safety, liability, regulation, data and cybersecurity and on use cases ranging from passenger carrying pods and road vehicles to freight and multipurpose multimodal last-mile transport. He is an Advisory Group member of BSI's CAV Vocabulary initiative, as well as a Steering Group member of BSI's PAS 1883:2020 Operational design domain (ODD) taxonomy for an automated driving system.

Jiayu Wu PhD is the Reader in Intelligent Mobility Design at the Royal College of Art (RCA) and leads and works on collaborative innovation research projects at the Intelligent Mobility Design Centre (IMDC), RCA, bringing together academics, industrial partners and students to design and deliver research and knowledge transfer projects for emerging mobility experiences. Her focus is digital integrated human experience and disruptive approaches for addressing existing and emerging mobility problems. Dr Wu is an innovation methods educator for technology and business

integration, and a professional user experience designer for the new mobility and automobile industries. She lectures on the impact of design innovation approaches in business development and social engagement and works with businesses of all sizes on concept design generation and production. Previously head of Tsinghua x-lab's Design Innovation Centre, Dr Wu specialised in incorporating design thinking in business development, industry joint projects and nurturing China's most academically talented students' spinout projects. As senior product developer at Volkswagen New Mobility Services, her focus was car sharing service design, new mobility solutions and urban transportation trends, including rolling out pilots in cities across China. Her research interests include exploring how user experiences influence cutting-edge technology in new and emerging markets and vice versa.

Hao Yue PhD is a professor and Chairman of the Department of Traffic Engineering, Beijing Jiaotong University, China, where he graduated with a PhD in transportation planning and management in 2009. His research interests include urban traffic engineering and transportation planning. He has led a number of pedestrian flow simulation and road network capacity studies and undertaken public transport planning projects for several cities in China.

Abbreviations

AB	autonomous bus
ABI	Association of British Insurers
ACE	autonomous, connected and electric
ACEA	European Automobile Manufacturers' Association
ACES	autonomous, connected, electric and shared
ACM	Association for Computing Machinery
ADAS	advanced driver-assistance systems
AI	artificial intelligence
AML	autonomous mobile locker
APTA	American Public Transportation Association
ASEAN	Association of Southeast Asian Nations
AV	autonomous vehicle
BEIS	Department for Business, Energy & Industrial Strategy
BEV	battery electric vehicle
BTC	Beijing Transport Commission
B2C	business-to-consumer
CAM	connected and automated mobility
CAV	connected and autonomous vehicle
CCAV	Centre for Connected & Autonomous Vehicles
C2C	consumer-to-consumer
DARPA	Defense Advanced Research Projects Agency
DFKI	German Research Center for Artificial Intelligence
DfT	Department for Transport
DOT	Department of Transportation
DRT	demand-responsive transport
DSRC	dedicated short range communication
DSSA	data storage system for automated systems
DVRP	dynamic vehicle routing problem
ENISA	European Union Agency for Cybersecurity
EPA	Environmental Protection Agency
ERIA	Economic Research Institute for ASEAN and East Asia
EV	electric vehicle
eVTOL	electric vertical take-off and landing
FAA	Federal Aviation Administration
FALM	first- and last-mile
FBS	free-floating bike-sharing
GDP	gross domestic product
GDPR	General Data Protection Regulation
GLA	Greater London Authority
GPS	Global Positioning System
GRC	governance risk compliance
HadCET	Hadley Centre Central England Temperature
HARPS	highly automated road passenger services
HCI	human-computer interaction

HEV	hybrid electric vehicle
HGV	heavy goods vehicle
ICE	Institution of Civil Engineers
IMDC	Intelligent Mobility Design Centre
IMU	inertial measurement unit
IoT	Internet of things
IPCC	Intergovernmental Panel on Climate Change
IT	information technology
ITF	International Transport Forum
ITS	intelligent transport systems
ITSC	<i>International Conference on Intelligent Transportation Systems</i>
IUA	International Underwriting Association
I2X	infrastructure to everything
KPI	key performance indicator
LSAVS	local shared autonomous vehicle services
MaaS	mobility as a service
MaaS-AP	MaaS-based accessibility planning
METI	Ministry of Economy, Trade and Industry
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MOC	Ministry of Construction
MORPH	Mobility, Ownership, Relationship, Personalisation, Hospitality
MoSP	mobility service provider
NGO	non-governmental organisation
NHTSA	National Highway Traffic Safety Administration
NIC	National Infrastructure Commission
NOAA	National Oceanic and Atmospheric Administration
ODD	operational design domain
ODI	Open Data Institute
OEM	original equipment manufacturer
ONS	Office for National Statistics
ORR	Office of Rail and Road
pcu	passenger car unit
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
P2X	people to everything
P4P	pricing for prosperity
RCA	Royal College of Art
RoSPA	Royal Society for the Prevention of Accidents
RUF	rapid urban flexible
SAE	Society of Automotive Engineers
SAV	shared autonomous vehicle
SDG	Sustainable Development Goal
SIP	Strategic Innovation Promotion Program
SMEs	small and medium-sized enterprises

SMMT	Society of Motor Manufacturers and Traders
SPB	station-based public bicycle
STC	Shanghai Transport Commission
SURCTC	Shanghai Urban Rural Construction and Transport Commission
TfL	Transport for London
TNC	transportation network company
TOD	transit-oriented development
TRL	Transport Research Laboratory
TRO	traffic regulation order
UCC	urban consolidation centre
UCL	University College London
UCLA	University of California, Los Angeles
ULEV	ultralow emission vehicle
ULEZ	ultralow emission zone
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
US	United States (adjective)
USA	United States of America (noun)
USTC	University of Science and Technology of China
UTC	urban traffic control
VAT	value added tax
VKT	vehicle kilometres travelled
VMT	vehicle miles travelled
V2I	vehicle to infrastructure
V2V	vehicle to vehicle
V2X	vehicle to everything