Transportation Research, Economics and Policy

Sylvie Mira-Bonnardel
Fabio Antonialli
Danielle Attias *Editors*

The Robomobility Revolution of Urban Public Transport

A Social Sciences Perspective

Springer

Transportation Research, Economics and Policy

Series Editors

More information about this series at http://www.springer.com/series/6647

Sylvie Mira-Bonnardel • Fabio Antonialli
Danielle Attias
Editors

The Robomobility Revolution of Urban Public Transport

A Social Sciences Perspective

Springer

Editors
Sylvie Mira-Bonnardel
Laboratory ISEOR Magellan
École Centrale de Lyon – Lyon University
Écully, France

Fabio Antonialli
Laboratory of Tribology and Dynamics of Systems
École Centrale de Lyon – Lyon University
Écully, France

Danielle Attias
Industrial Engineering Laboratory
École CentraleSupélec
Université Paris Saclay
Gif-sur-Yvette, France

ISSN 1572-4387
Transportation Research, Economics and Policy
ISBN 978-3-030-72975-2 ISBN 978-3-030-72976-9 (eBook)
https://doi.org/10.1007/978-3-030-72976-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

It is because the future is made of uncertainties, that it deserves our interest, passionately and collectively. If the games were already played, what would be the point of moving heaven and earth to try to change the course of things? Acting on the present to prepare a future in which we want to live is the very essence of foresight, to which this book invites us. On the path we are going to take toward this future, we will all have the first step to take and to engage in a mobility transition; the scenario of inaction is no longer tenable.

Mobility is the breathing of the territory, and making it evolve means directly changing people's lives. Therefore, the question that arises with automated vehicles is whether they have the power to transform territories and lifestyles and access to the city's resources. This is the approach that the prospective workshop *La vie robomobile* is leading, since its foundation in 2017, by the Ministry of Ecological Transition, the Gustave Eiffel University, and the Laboratoire Aménagement Economie Territoires, to which Stratys has been actively contributing since its beginning.

It is up to society, individuals, and regional players to decide whether or not to take up technological innovations and to support the emergence of new models, particularly in the field of public transport and urban mobility. Just as the hegemony of the automobile can be problematic, it is not a question of switching to a new uniform and monolithic model in the future, where a single other mode would replace the solo car. For transport automation, several socio-technical models exist: the choice is possible, as long as we fully grasp the subject, experiment, test, keep our feet on the ground, and of course anticipate.

That's the whole point of an approach based on a bundle of solutions, which has its natural extension with Mobility as a Service. Autonomous shuttles fit in perfectly with this logic and are the translation into action of a public policy in favor of shared mobility and mobility as a vector of social ties and territorial cohesion. This is a sign of mobility where public authorities intend to play an active role in the regulation of a mobility market in the broadest sense, regardless of whether it is motorized or not, automated or not.

Many uncertainties remain regarding the economic model, such as the impacts on lifestyles, actual uses, the concrete scope of the technology, the ability to finance these changes, and the adequacy of the legal framework. However, instead of seeing them as constraints or obstacles, these uncertainties are equally grey areas in which everything or almost everything remains to be invented. This collective book will provide guidelines and tools to help you understand the potential for "game change" in the automation of public transport in the regions.

Christian Long
Foresight Consultant,
Specialist in Mobility Issues – Director of Stratys
Paris, France

Introduction: Bricks and Mortar of the Urban Public Transport Revolution

With more than a half of the world's population currently living in urban areas, mobility has become a key factor affecting citizens' well-being and life quality, as well as economic development. Policy makers are well aware of the mobility leveraging effect, and regulation is rapidly evolving.

Over the past two decades, society has been witnessing how technological, political, and societal changes have been transforming individual and collective urban mobility. Driven both by newcomers and traditional players, by disruptive as well as incremental innovations, by technology as well as uses, mobility offered today has become more diversified and more complex than ever.

This transformation has been mainly enabled by the widespread adoption of internet-connected devices (e.g., smartphones and tablets) and by innovative business models, technologies, and use-cases that arose from this rapid digitalization, such as peer-to-peer, and two-sided markets providing several mobility schemes: car-sharing, car-pooling, bike sharing, free-floating (cars, bikes, electric scooters, etc.), and ridesharing as well as ride hailing either for long distances and for urban micro-mobility.

The sum of these innovations has contributed to forge the concept of Mobility-as-a-Service (MaaS), which aims at offering customized transport services by uniting already existing transport solutions and transport providers, and offering them in a package to customers on a single subscription – and via a single interface of a service provider.

In that new landscape of MaaS, public transport acts as a backbone by linking all the other mobility offerings together in order to provide a seamless multimodal journey from point A to B for urban travelers. Thus, its stakeholders are leveraging a real paradigm shift accordingly with technological innovations, policy and regulation evolution, and travelers' behavioral changes. The collateral effect expected from this new globalized approach of mobility is the reduction of vehicle ownership, and its corollary congestion, road accidents, and pollution in cities.

Among these many innovations, public transport operators have been experiencing the arrival of Autonomous Vehicles for Collective Transport (AVCTs). At the current early stages, these vehicles are capable of autonomously carrying up to 15 passengers and are proposed to fulfill the first- and last-mile requirements as well as micro-transit services, aiming to transform the traditional fixed-route public transport into a customized on-demand offering. In the upcoming years, as shown by current experimentations, autonomous driving can be deployed by means of different types of AVCTs like regular-sized buses, five-seater cars, or even drones and helicopters. This transformation toward robomobility is a tangible revolution for urban public transport mobility.

Departing from the perspective of the social sciences, the book presents – in a holistic manner – how this revolution is happening; what are the major cornerstones for the implementation of robomobility; and, more largely, which levers are transforming urban mobility. It aims at answering several following substantial issues: *What is robomobility and what does it imply for the different stakeholders of the public transport ecosystem? How do policy makers integrate this innovation and how ready the regulations are? How do citizens take part in this transformation? What is the level of user acceptance for this new type of mobility? How to measure the economic impact of deploying autonomous collective vehicles in a local ecosystem? How decision-making processes are defining the public transport transformation?*

For now, the technology itself is no longer the major hindrance for autonomous fleet implementation, and their deployment speed is very much linked to their socio-economic impacts. Therefore, this was written from the viewpoint of the social sciences to prospect mobility challenges and forthcoming innovations. We aim to analyze to which extent innovation may prove beneficial or adverse in achieving common societal and economic goals by presenting a better understanding of mobility ecosystems and how their stakeholders perceive and value innovation's future use.

The book is written by a multidisciplinary and transnational team of academics – experts in the field of urban mobility – who work on three different levels: theoretical, tactical, and operational.

On the theoretical level, the book proposes a large review of research conducted on urban mobility by several scholars around the world for the last decade. The major stakes are taken into account and analyzed at their current stage as well as with a prospective view on politics, society, and technology.

The tactical dimension is tackled by in-depth analysis of mobility innovations and more specifically robomobility experimentations and the lessons to be learned concerning user behavior, governance, and integration in a global MaaS ecosystem.

Within an operational perspective, the book proposes two tools to evaluate and simulate the impact of robomobility: one tool is a decision support tool that helps to conduct an economic impact evaluation, and the other one is a methodology to assess the regulation openness for autonomous driving.

By combining these three levels: theoretical framework, real case studies, and analytical tools, the book brings relevant insights both from an academic and from an empirical standpoint.

The book is divided into two parts: the first part focuses on robomobility, and the second part broadens the viewpoint by placing robomobility into the larger range of urban mobility innovations.

Part I focuses on the different key points of robomobility implementation into public transport networks. Because robomobility may introduce remarkable changes in the way public transport meets their demand, its deployment represents the major challenge for public operators and policy makers as well as regulators. This part presents the big picture of autonomous public mobility and goes deeper into its three big challenges: policies, regulation, and economic impact. This part is concluded by the detailed presentation of a large experimentation on a European scale.

Part I comprises five chapters that are detailed hereafter.

In Chap. 1, Fabio Antonialli brings an overview of the evolution of automation in public transport, from the first automated metros until the most recent advances and trials in mixed-traffic conditions with Autonomous Vehicles for Collective Transport (AVCTs). It presents a typology of uses with five stages of on-demand services with AVCTs exemplified by many cutting-edge experimentations distributed among the five proposed stages. The arrival of AVCTs shows an imminent disruption in the history of public transport, reconfiguring not only the forms of use, but also its whole business model structure.

In Chap. 2, Jeehoon Ki presents the evolution of government's policy on AVs since the early 2010s in Asia and Europe. To highlight different approaches, Korean and French cases are selected, and the milestones in the evolution of their policies and legislation are compared. Both qualitative and quantitative ways are employed, and the latter is done by a bibliometric analysis. Korea and France commonly set AVs as a national strategic sector between 2013 and 2014, and large-scale R&D investment schemes, various policy measures, and relevant legislation followed, including various trials for AVCTs. Interestingly, each country takes its own unique. France opted for a demand-pull approach, focusing on making AVs socially acceptable. Korea, by contrast, went with a tech-push approach, focusing on making AVs technologically available. This chapter contributes to a better understanding of the different types of interaction between government's policy and the transformation toward robomobility.

In Chap. 3, Sylvie Mira-Bonnardel and Elizabeth Couzineau analyze the regulatory framework for the deployment of autonomous public transport. After providing a general overview of the international and European organizations involved in regulatory statements and the branches of law framing regulation for public transport, the authors propose a tool to evaluate the level regulatory openness toward robomobility, the ROAD index (the **R**egulation **O**penness for **A**utonomous **D**riving index). Taking into account regulations and policy making processes, the authors distinguished a set of four variables to measure the level of national or local readiness for the implementation of autonomous collective vehicles on open roads. ROAD index helps to evaluate regulation as facilitator or barrier to robomobility and to understand in which way decision makers can leverage on regulation to make it build a favorable framework for mobility innovations.

In Chap. 4, Fabio Antonialli, Sylvie Mira-Bonnardel and Julie Bulteau address the issue of economic impact evaluation of robomobility assuming that the integration of autonomous buses into public networks is mainly dependent on costs and breakeven points for operators and local government. Research quantifying return on investment specifically in academic settings are sparse. This chapter aims to introduce a simulation tool: EASI-AV (**E**conomic **A**ssessment of **S**ervices with **I**ntelligent **A**utonomous **V**ehicles). This is designed as a decision-making tool to support public policies on whether or not implementing innovative mobility services. EASI-AV proposes to (a) assess the global economic impacts of deploying fleets of AVCTs in comparison with traditional public transport modes, and (b) help local authorities to build scenarios integrating autonomous buses into their public network and imagine new business models. The simulation is based on the Total Cost of Ownership (TCO) approach and includes four aspects that may be used independently: (1) fleet size dimensioning, (2) the TCO calculation with internal costs and local externalities, (3) the business model simulation, and (4) the global impact assessment in comparison with other transport modes. EASI-AV was tested with real data from pilot sites in Europe, and the results prove it to be fully relevant.

In Chap. 5, Dimitri Konstantas presents a large-scale European experimentation: the AVENUE project. The AVENUE vision for future public transport in urban and suburban areas is that autonomous vehicles will ensure safe, rapid, economic, sustainable, and personalized transport of passengers, while minimizing vehicle changes and maximizing vehicle utilization. The goal of the project is to provide door-to-door, on-demand autonomous public transport services allowing commuters to benefit from the full capabilities of autonomous busses. However, the road to a public transportation service is not so simple. Legal and regulatory requirements create barriers and obstacles, raising the costs and delaying the deployment of the services. In spite of the efforts from the European Commission for a harmonization of the homologation process, urban public transportation is under national and local legislation, creating a highly fragmented European environment. In this chapter, the author presents the experience in setting up and deploying autonomous buses in two cities, Geneva and Copenhagen.

Part II develops a broader view integrating robomobility in the larger perspective of urban mobility innovation embedded in societal contexts. When new mobility services are incorporated in the city network, this integration takes a step closer to transform the urban public transport. This transformation comes with the integration of a user perspective in the design of mobility solutions and with the development of new business models for public transport targeting the development of more sustainable mobility systems. This part is concluded by a prospective analysis of how governance models can put the user at the center of urban mobility.

Part II comprises five chapters that are detailed hereafter.

In Chap. 6, Ouail Al Maghraoui, Flore Vallet, and Jakob Puchinger deal with the formulation and innovation processes of mobility solutions from the viewpoint of designers (vehicle providers, start-up companies developing digital mobility applications, mobility operators, etc.). It is becoming increasingly important to take the door-to-door experience of travelers, and of other users of mobility systems, into account. The authors advocate that user-centered insights are useful at different stages of a solution development. When mobility solutions are not yet on the market, trials are mostly conducted to evaluate technological maturity (of autonomous shuttles for instance). Testers in these trials can say more about their experience and the value of the solution if asked to. When mobility solutions are on the market, there is a need to capture the experience of travelers and uncover their door-to-door issues through a systemic mobility diagnosis. This type of problem diagnosis can be used to feed innovation approaches, reveal value buckets for companies, and bring meaningful solutions for both travelers and other users. Finally, the authors discuss the applicability and the potential of the recommendations for different mobility stakeholders.

In Chap. 7, Ayman Mahmoud, Tarek Chouaki, and Jakob Puchinger investigate the potential integration of innovative mobility modes with urban public transport. The authors emphasize the design of future autonomous on-demand transportation systems and the interactions of these systems with public transport. These new modes pose several implementation challenges for public transport system design, including strategic, tactical, and operational choices when projecting the implementation. The impact on the overall urban transport systems is considered along with the sustainability issues. The chapter proposes to review the current literature and state of the art, investigates technological developments, and finally develops some visions and research perspectives on the future integration of on-demand transport in public transport systems.

In Chap. 8, Adriana Marotti De Mello, João Valsecchi Ribeiro De Souza, and Roberto Marx discuss how new business models may be integrated into public transport in order to contribute to the development of more sustainable mobility systems. Based on the precepts that Mobility-as-a-Service (MaaS) is a viable alternative to improve the conditions in which public transport is accessed and innovations in public transport play an essential role in the development of sustainable urban mobility in cities, the authors highlight a framework of the barriers and drivers associated with the implementation of these business models, from the firm's level – strategic and operational aspects – to the institutional system level in which these new businesses are part of. The authors rely on examples of new businesses that are being developed in emerging countries like Brazil and China, where public transport represents one of the main alternatives for commuting in large urban centers.

In Chap. 9, Rodrigo Marçal Gandia proposes that the MaaS phenomenon entails the integration of different public and private transport, considering public transport as a backbone. The applicability of MaaS schemes is closely related to efficient public transport networks, which is not a reality in several developing countries. In this chapter, the author presents a new perspective on MaaS. Thus, we believe that for a revolution in public transport, MaaS can be a catalyst. The author considers MaaS as a business model that can be modular and adaptable to several realities. By considering public transport as the backbone (whether efficient or not), its eventual inefficiency can be balanced with the integration of private actors, corroborating with the context of smart cities, and new alternatives for private transport means (e.g., autonomous vehicles and shuttles). To this end, the author considers the theoretical precepts of business ecosystem, product-service system (PSS), eco-innovation, and consumer behavior (via the act of sharing). Approaches like these can guide the applicability of MaaS in the context of smart cities and new business model perspectives, such as Corporate MaaS and Rural MaaS.

In Chap. 10, Danielle Attias addresses the issue of urban mobility governance for public transport innovations. Economic, financial, social, and environmental issues are at the heart of ecological transition programs in many major cities globally. This new governance model concerns public transport and the management of innovative mobility, including mobility on-demand. However, the modes of management of public transport are contrasted, being different according to the geographical location of the city, the citizens' way of life, and the history of each metropolis. What remains common to all cities, however, is an ambition and a desire to integrate in their transport network radical innovations such as autonomous shuttles and digitalization tools such as MaaS. The future of mobility is part of a robomobility approach, including autonomous vehicles. This forward-looking vision will radically challenge the relationships between users, citizens, and city governance.

To reimagine the future of urban public transportation is to rethink the future of cities through new technologies, regulations, user behavior, and business models. If the urban public transport revolution is a story written on a daily basis, there is no doubt that the 2020 pandemic crisis has accelerated the transformation. This book lays bricks and mortar for this new story of urban mobility.

École Centrale Lyon
Écully, France
sylvie.mira-bonnardel@ec-lyon.fr
Sylvie Mira-Bonnardel

Laboratory of Tribology and Dynamics of Systems
École Centrale Lyon
Écully, France
fabio.antonialli@ec-lyon.fr
Fabio Antonialli

Acknowledgments

As editors of this collective book, we would like to thank each one of the 14 authors who took their time to write their contributions to this project. We would also like to thank all the members of the urban mobility ecosystem for inspiring us and opening the doors so that we could conceive this work. In particular, we thank the transport operators Sales-Lentz, TPG, Holo and Keolis-Lyon and the autonomous vehicle manufacturer Navya for their insights and help with data for various chapters.

Our discussions with the Atelier Prospectif de la vie robomobile (Robomobile Life Prospects Workshop) provided a favorable framework for building anticipation scenarios on robomobility. Furthermore, thanks to our meetings with GERPISA (Permanent Study and Research Group on the Automotive Industry and Employees), we were able to open this book to young researchers and continue our reflections on the future of mobility.

At last, we recognize the dynamism and commitment of the European Commission, especially by means of its Horizon 2020 program (H2020[1]) for the various research projects on autonomous vehicles and urban mobility, among which we highlight the AVENUE[2] project through which several contributions for the chapters arose.

[1] European Commission, Horizon 2020 program. Available at: https://cordis.europa.eu/programme/id/H2020-EU.3.4.

[2] This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 769033 (AVENUE project).

Contents

Part I Robomobility Implementation into Public Transport Networks

1 Autonomous on-Demand Vehicles and the (R)evolution of Public Transport Business Models . . . 3
Fabio Antonialli

2 Evolution of Government Policy for Autonomous Mobility: Korean and French Cases and Their Differences . . . 23
Jeehoon Ki

3 How to Assess Regulation Openness for Autonomous Driving in Public Transport? The ROAD Index . . . 51
Sylvie Mira-Bonnardel and Elizabeth Couzineau

4 Economic Assessment of Services with Intelligent Autonomous Vehicles: EASI-AV . . . 85
Fabio Antonialli, Sylvie Mira-Bonnardel, and Julie Bulteau

5 From Demonstrator to Public Service: The AVENUE Experience . . . 107
Dimitri Konstantas

Part II Integrating Robomobility in the Larger Perspective of Urban Mobility Innovation Embedded in Societal Contexts

6 Recommendations for a User-Centered Design of Mobility Solutions . . . 133
Ouail Al Maghraoui, Flore Vallet, and Jakob Puchinger

7 The Integration of Innovative Mobility into the Urban Transport Network: A Literature Review . . . 153
Ayman Mahmoud, Tarek Chouaki, and Jakob Puchinger

8 Public Transport in Emerging Countries: From Old Dilemmas to Opportunities for Transition to Sustainable Mobility Through the Case of Brazil 167
Adriana Marotti De Mello, João Valsecchi Ribeiro De Souza, and Roberto Marx

9 MaaS as a Catalyst for the Public Transport Revolution in Developing Countries 181
Rodrigo Marçal Gandia

10 Reflexions on Urban Mobility Governance: Moving Towards Tomorrow's Robomobility 193
Danielle Attias

Conclusion 211

Index 215

Part I
Robomobility Implementation into Public Transport Networks

Chapter 1
Autonomous on-Demand Vehicles and the (R)evolution of Public Transport Business Models

Fabio Antonialli

Abstract This chapter brings an overview of the evolution of automation in public transport, from the first automated metros until the most recent advances and trials in mixed-traffic conditions with Autonomous Vehicles for Collective Transport (AVCTs). It presents a typology of uses with five stages of on-demand services with AVCTs exemplified by many cutting edge experimentations distributed among the five proposed stages. The arrival of AVCTs shows an imminent disruption in the history of public transport, reconfiguring not only the forms of use but also its whole business model structure.

Keywords Autonomous vehicles · Business models opportunities · On-demand services on public transport · DRT · Public transport

1.1 Introduction

Over the past few years, our society's collective imaginary has been captured by illustrations of modern, bustling cities buzzing with autonomous vehicles everywhere. Car manufacturers and tech giants have been recently competing in a multi-billion-dollar race to make this vision a reality. In the meantime, governments worldwide are busy revising and adapting their legal framework to accommodate the era of robomobility. Thus, the debate has quickly shifted from whether it is going to happen, to when and how it will happen (Viegas, 2017).

F. Antonialli (✉)
Laboratoire de Tribologie et Dynamique des Systèmes (LTDS),
École Centrale Lyon, Écully, France
e-mail: fabio.antonialli@ec-lyon.fr

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_1

As stated by Mira-Bonnardel and Attias (2018), we may expect in the next 20 years a genuine transformation that may pave the way for a new urban mobility paradigm. For the authors, this revolution of urban areas will likely occur by the arrival of Autonomous Vehicles for Collective Transport (AVCTs).

Indeed, as stated by Merat, Madigan, and Nordhoff (2017), as the implementation of more advanced sensors, radars, and navigation technologies in vehicles increases, there is now a potential for the mass-deployment of a new form of publicly available, electrically operated, driverless minibuses for urban environments. If successfully deployed, these automated minibuses and similar automated vehicles can provide flexible and cost-efficient solutions for serving both peak and off-peak demand, parallel and as feeders to trunk lines (Ainsalu et al., 2018).

In this sense, the technology itself is no longer the major hindrance (Poorsartep, 2014), the main roadblocks that AVCTs are now facing are consumer acceptance and regulatory frameworks (Enoch, 2015; Schellekens, 2015). On the other hand, several studies have shown that autonomous driving has reached a high degree of familiarity among the population. The acceptance rates for fully AVCTs ranges between 68% and 77% (Pakusch & Bossauer, 2017).

Thus, urban centers could strongly benefit from the introduction of AVCTs, since they are able to compete with automobiles by price and even be more effective than traditional public transport buses (by taking 15 instead of 150 passengers), moving on flexible routes instead of fixed ones, and being on-demand instead of on-schedule (Ainsalu et al., 2018). As stated by Fagnant and Kockelman (2018), automated mobility-on-demand is based on the idea of shared fully-automated vehicles which might rapidly induce the shift from privately owned personal vehicles to fleet services by driverless, demand-responsive vehicles, shared among a mix of users.

In this regard, we are on the verge of experiencing a revolution in the business models of public transport operators, having for the first time a customizable, autonomous, on-demand, collective, public, and shared transport solution for passengers.

This chapter aims to provide an overview of the recent evolution of automation in public transport as well as to propose different stages of on-demand services with AVCTs and their respective business models opportunities.

Besides this introduction, in Sect. 1.2, the chapter describes a brief evolution of automation in public transport, dating back to the first automated railway lines, until the most recent advances and trials in mixed-traffic conditions with AVCTs. Section 1.3 proposes a taxonomy for on-demand public transport services and provides examples with autonomous shuttles for the proposed levels. Section 1.4 provides a panorama of innovative business models that can emerge due to the implementation of on-demand autonomous shuttles, and lastly, Sect. 1.5 brings the conclusions of the study.

1.2 (R)evolution of Public Transport: From Rails to Streets

1.2.1 The Evolution of Public Transport Automation – Automation on Rails

The robotics and automation industries have been contributing to many aspects of our daily lives for over five decades now, with several IT-related industries based on mobile information technology emerging due to the so-called fourth industrial revolution (Schwab, 2017). In this context, the transport and mobility industries are no exceptions. In fact, public transport has been ahead of the curve for many years, with records tracing back to 1968 when the world's first full scale automatic railway opened in London Underground's Victoria line (Day & Reed, 2011).

Since then, Grades of Automation (GoA) in railways have been evolving, ranging from GoA 0 – no automation at all, to GoA 4 – fully automated operations without any on-train staff (UITP, 2011). In fact, when considering GoA 4, also known as UTO (Unattended Train Operation), the first commercial lines with this type of technology date back to the early 1980s; a good example is Vancouver's SkyTrain, whose operations began in 1985, and today is the third longest automated metro system in the world (Druker & Nassar, 2016), behind Kuala Lumpur and Singapore.

According to the International Association of Public Transport (UITP, 2011), there are currently over 648 km of GoA 4 automated metro-tracks in operation worldwide, spread over 41 lines that serve up to 644 stations in over 25 cities in the globe, among these: Barcelona, Busan, Copenhagen, Dubai, Kobe, Lille, Nuremberg, Paris, Singapore, São Paulo, Taipei, Tokyo, Toulouse, and Vancouver. According to UITP's estimates, the total number of automated metro-tracks is likely to reach 1400 km by 2025. In fact, if one considers small-capacity private lines (e.g., airport services, people movers), the world today has over 204 fully-automated rail lines to serve passengers.

In this sense, automation in public transport is already commercially available, closer, and more present in peoples' lives than they imagine. However, trains and metros operate in well-controlled environments with fewer uncertainties and external interventions than those faced by cars and buses for example.

That is, urban streets and avenues are much more complex and challenging environments than rails. Automated metros do not have to face level crossings, traffic lights, traffic jams, pedestrians, cyclists, and many other uncertainties and variables that make automation extremely complex for the mixed-traffic environment of cars and buses. However, even in the face of these barriers and challenges, automation has been getting off the rails and into the streets and avenues of cities around the world.

1.2.2 *The Revolution of Public Transport Automation – The Emergence of AVCTs*

The earliest record of Autonomous Vehicles (AVs) dates back to the mid-1970s in Japan, with a prototype capable of tracking white street marks at speed up to 30 km/h. Ten years later, the first car-like robot would emerge in Europe in Bundeswehr University as part of the "Prometheus" project and in America with the project "No hands across America" from Carnegie Mellon University, which has developed a vehicle capable of performing autonomous navigation from Washington DC to San Diego with 98% automated steering and manual longitudinal control (Lima, 2015).

However, the biggest watershed in AVs' research and development happened in 2004/2005 in the United States with a series of annual public challenges, called DARPA Gran Challenges (Gandia et al., 2018), from which countless contributions and advances have been made in vehicle automation, bringing the indoors-laboratory research to the streets and shifting the focus to beyond technological aspects. As a consequence, AVs are today a potentially disruptive and beneficial change to the current transportation business model (Attias, 2017).

Similarly to GoA's typology used for railways, the Society of Automotive Engineers (SAE, 2016) have also created a taxonomy for defining levels of automation for on-road motor vehicles. It comprises six levels, ranging from ZERO (no driving automation) to FIVE (full driving automation). As of 2020, in the current stage of technology development, level 2 vehicles are already being marketed, such as: Tesla's models S, X, Y; Mercedes-Benz's S65; Infinity's Q50S; BMW's 750i xDriv; and Audi's A8 (Antonialli, 2019).

Among the many promised benefits of vehicular automation, one can highlight that AVs would facilitate driving, increase road safety, reduce emissions of pollutants, reduce traffic jams, as well as allow drivers to choose to do different things other than driving. Thus, access to fully automated vehicles would also improve mobility for those who cannot or do not want to drive (Attias, 2017; Enoch, 2015; Schellekens, 2015).

On the other hand, from the technology standpoint, there is still a long way to maturity and reliability of AVs, since – to date – there are no level 5 AVs commercially available (Lambert & Granath, 2020), current AVs require constant human monitoring and are prone to sudden harsh breaks and speed limitations. There are also many security and reliability issues still to be solved, as well as several aspects regarding consumer acceptance and regulatory frameworks (Fagnant & Kockelman, 2015; Pakusch, Stevens, Boden, & Bossauer, 2018).

Furthermore, it is worth highlighting that the current level 2 vehicles already being marketed are private luxury cars aimed at the upper classes of the population. Thereby, Mira-Bonnardel and Attias (2018) highlight that fleets of AVs will not be seen on the roads right away. For the authors, it is likely that the widespread adoption of AVs may firstly be authorized for collective transportation, thus offering a solution for larger cities that struggle to provide adequate public transport to support their residents' needs.

In fact, just as for the rail sector, public urban road transport is also ahead of the curve. Besides the well-advanced tests by Google's subsidiary Waymo (with their 5-seater AVs), within the scope of current deployments, the most widely tested upper-automation level vehicles (SAE's levels 3 and 4) are Autonomous Vehicles for Collective Transport (AVCTs) (Antonialli, 2021; Iclodean, Cordos, & Varga, 2020).

AVCTs are electric autonomous buses equipped with a wide-range of sensors and cameras that today are capable of carrying up to 15 passengers with the main goal of fulfilling the first- and last-mile parts of the commute, as well as micro transit for city centers, central business districts, university campuses, airports, shopping malls, hospitals, etc. (Harris, 2018). By being in the higher automation levels, such vehicles do not require the constant monitoring and intervention of a human operator (in fact, these shuttles don't even have steering wheels or pedals). However, due to current legal restrictions, a human operator must always be on board to take control of the vehicle (with a joystick-like controller) in case of automation failure.

With the aim of carrying out a comprehensive benchmark on experimentations with AVCTs, Antonialli (2021) identified 176 experimentations worldwide that unfold in 142 cities spread over 32 countries enabled by 20 different autonomous shuttles manufacturers (Fig. 1.1). However, not only due to the current technological limitations of automation for mixed-traffic conditions but also due to regulatory constraints and consumer acceptance, only 5.71% of these deployments were regular permanent services (all in dedicated/segregated lanes). The majority were short to mid-term trials (81.15%) with the aim of allowing consumers to examine, use,

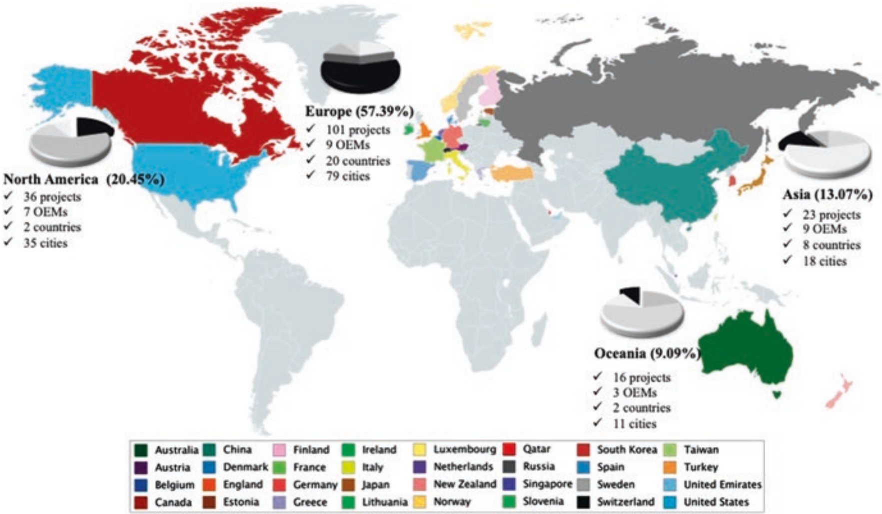


Fig. 1.1 Worldwide experimentations with AVCTs. (Source: Antonialli (2021))

and test the services, and the remaining 13.14% were showcases to promote the technology and the services.

From a historical perspective, one of the first services with AVCTs was offered by the Dutch company 2getthere (Iclodean et al., 2020). Their first applications were pilot tests with automated guided shuttles on dedicated lanes at Amsterdam's Schiphol airport in 1997, and in Rotterdam's business park Rivium in 1999.

In 2006, their services in Rotterdam (operated by the local transport operator Connexxion) were updated with more advanced shuttles and are still commercially operational today. In 2010, the company opened their first permanent system at Masdar City (United Emirates), and today is engaged in delivering the third generation Rivium project, as well as autonomous shuttles at Brussels' Zaventem airport and in the Bluewaters island in Dubai (2getthere, 2018). The company can be seen as the pioneer in commercial operations with AVCTs; however, their main services are offered in dedicated lanes and segregated infrastructures; in this regard, their operations are not yet completely inserted in mixed traffic environments.

On the other hand, the major advances in AVCTs tests in mixed-traffic conditions occurred from 2014 onwards with the emergence of two pioneering French start-ups: Navya and Easymile. According to Antonialli (2021), from the 176 sampled deployments, the two companies together accounted for a total of 78.5% of the number of shuttles used, and more than half (51.13%) of the total of experimentations were in mixed-traffic conditions.

Founded in 2014, with headquarters in Toulouse, EasyMile is the result of a joint venture between Ligier (vehicle manufacturer), and Robosoft (high tech robotics company and former autonomous shuttle manufacturer). Their autonomous shuttle, the EZ10, was developed with the aid of the European Commission funded project CityMobil2 (Alessandrini, 2018). On the other hand, Navya is EasyMile's main contender (Fluhr, 2017). Also founded in 2014, with headquarters in Lyon and Paris, they launched their ARMA autonomous shuttle in October 2015.

Also worth highlighting is the growing relevance of the American market-newcomer Local Motors (Antonialli, 2021; Fluhr, 2017), the company developed their vehicle OLLI, using 3D printing technology and their shuttle is equipped with IBM's Watson artificial intelligence.

Antonialli (2021) also identified that the vast majority of experiments with AVCTs (94.18%) were offered as Regular-Line Transport (RLT) – with predetermined fixed and looped routes, fixed stops, regular intervals between vehicles, and with preset hours of operation. In this respect, RLT with autonomous shuttles already represent an important evolution in the business models of Public Transport Operators (PTOs), not only by bringing high-level automation vehicles to urban roads in mixed-traffic conditions but also by exposing the general public to the technology, allowing them to test and gain more confidence on using these vehicles on a regular basis.

However, the (still latent) potential for a revolution in the business models of PTOs lies on the remaining 5.82% of experimentations that were offered as Demand-Responsive Transit (DRT). In DRT services, by using an app on their smartphones, users can hail an AV according to their specific travel needs (Winter, 2015). Thereby, shuttles do not need to circulate at fixed intervals of time, neither follow fixed with pre-defined stops or lines.

The next session better details the disruptive potential of this business model for PTOs, as well as proposes a taxonomy for defining levels of on-demand service for public transport.

1.3 Collective, Public, and Shared: The Disruption of on-Demand Public Transport

As pointed out by Barrett, Santha, and Khanna (2019, p.3) from the L.E.K. consulting group, there is no universally accepted definition of on-demand public transport; however, they chose to define it as a "form of publicly subsidized transport that takes multiple passengers within a predefined area from one place to another on a next-available, or pre-book basis".

This type of transport is most applicable when there is not enough demand for a frequent and direct mass transport solution (Mulley, Nelson, Teal, & Wright, 2012). It focuses on optimizing the journey for groups of passengers going to or from a hub for a subsidized price, which may result in relatively longer waiting and travel times compared to other commercial on-demand services (e.g., Uber, Didi Chuxing, Lyft, and taxis) and will more likely involve shared journeys – resembling here (but in a subsidized way) services like UberPool and LyftLine.

On the one hand, the business model of on-demand public transport (DRTs) has been in place since the 1970s; in fact, there are over 40 cities globally that are currently experimenting with human-driven DRT services (Barrett et al., 2019; Pettersson, 2019). On the other, although existent for many years, DRTs have overall proved to be quite expensive to operate, requiring significant public subsidies and have therefore not proved cost-effective to scale up (Barrett et al., 2019).

According to the authors, trunk-lines with high demand and frequency of services are generally well patronized and have higher cost recoveries (proportion of costs covered by fares). On the other hand, feeder-lines (e.g., first- and last-mile services) are typically less frequent and thus suffer from lower patronage, resulting in much lower cost recoveries, thus requiring higher government subsidies. DRT services fall into this latter category.

1.3.1 Operating Costs of AVCTs

One of the most significant operating costs for public transport operators are crew costs (mainly drivers' salaries). As pointed out by Tirachini and Antoniou (2020) – based on their calculation for Australia – depending on the bus type, the costs with drivers can add up to 70% of the total operating costs. In Singapore, they average

40% (Ongel et al., 2019), 53% in Japan (Abe, 2019), and 42% in Sweden (Jansson, 1980) – indeed, even in a 40-year-old study, driver costs already proved to be significant. Thus, by simply extrapolating the arithmetic mean of these previous studies, one can say that driver costs can add up to approximately half (51.25%) of the total operating costs. More details regarding the economic impact of AVCTs are given on Chap. 4.

Thus, the arrival of AVCTs can help balance this scale not only by reducing operating costs for PTOs but also by being able to offer flexible on-demand transport with significant potential for lower density, first- and last-mile trips, offering a more efficient service with better levels of user experience. Thereby, it is clear that the use and integration of AVCTs for on-demand services, with dynamic routes and real-time booking, have the potential to significantly improve services and provide solutions to many of the problems encountered today in developing cost-effective, sustainable, and efficient public transport.

1.3.2 On-Demand Stages for Autonomous Public Transport Services

It is important to highlight that not all DRT services are the same. According to Barrett, Santha, and Khanna (2019, p.9), business models and level of service may vary considerably from context to context and across key dimensions, such as route (flexible, fixed, or semi-fixed), schedule (flexible or fixed), fleet (size and variety), relationship to existing public transport network (supplementing or replacing existing routes), technology (digital platforms that may be integrated with the PTO app or via stand-alone applications), service area (urban core, urban fringe, rural areas), and branding (PTOs may choose separate branding for the DRT service, may or may not identify the platform provider, etc.).

In this sense, Fig. 1.2 aims to categorize and synthesize the possible stages of on-demand service for public transport that can be offered by PTOs to their local communities. Following the figure, some real examples with AVCTs are presented for the proposed stages. Possible alternative business models that can be pursued with this type of innovation over traditional public transport services are discussed in Sect. 1.4.

As illustrated in Fig. 1.2, on-demand service stages for public transport can range from ONE (without DRT) to FIVE (full on-demand DRT), and can be applied for both human-driven buses and autonomous shuttles. Considering that the main advances with AVCTs have taken place from 2014 onwards (just over 5 years ago), there is still much to be done in terms of improving autonomous driving technology, as well as the pending issues on the legal framework, and the challenges regarding user acceptance and trust. Furthermore, the on-demand market is still in its very early stages, with relatively few scale deployments, with most cities and regions still in piloting stages (Barrett et al., 2019 p.10).

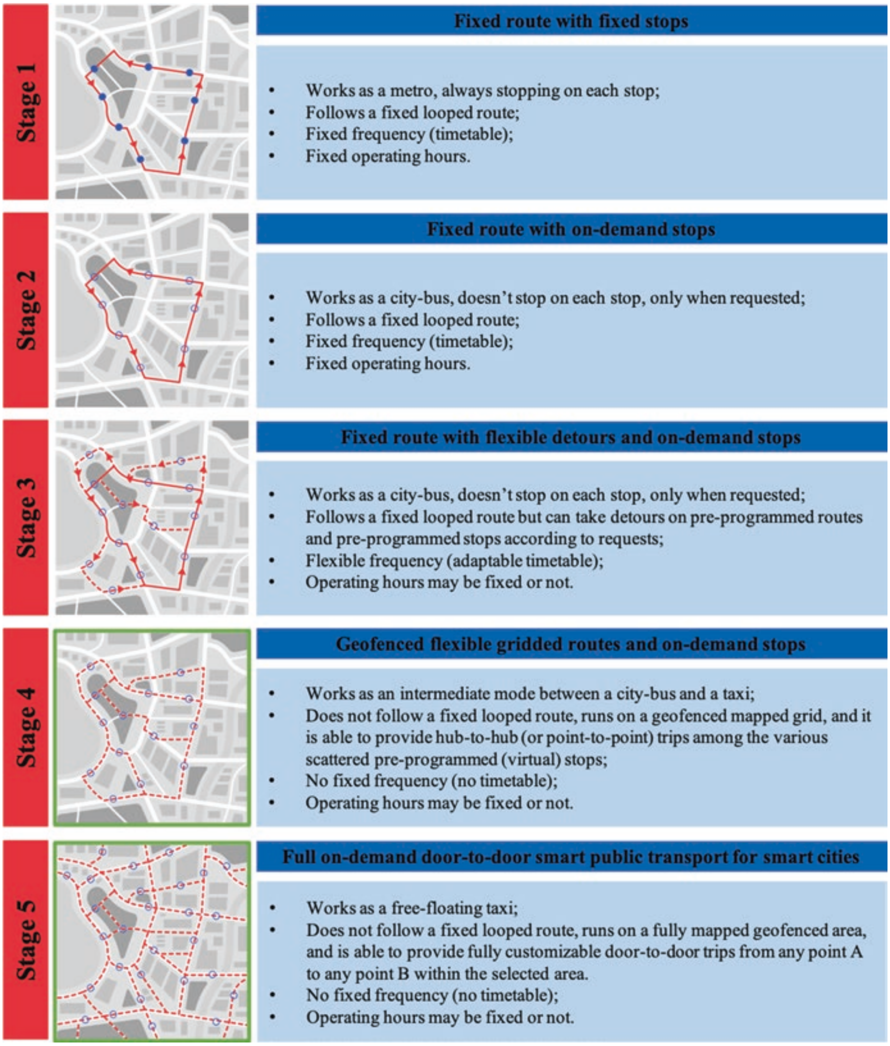


Fig. 1.2 Levels of on-demand service for public transport. (Source: prepared by the author)

Stage 1 – Fixed Route with Fixed Stops

The majority of the current existing services with AVCTs fall into this stage. As exemplified by Antonialli (2021), with 94.18% of the sampled projects. That is, similarly to the GoA 4 automated trains and metros, the majority of current trials and services with AVCTs run in predefined fixed routes (either in mixed-traffic or segregated/dedicate lanes), follow a fixed schedule with fixed frequency and operating hours, and always stop on each of the stops/stations.

An important example of trials within the proposed stage 1 is the pioneer European Commission funded project CityMobil2 carried out from September

2012 to August 2016. The project aimed at fostering the implementation of AVCTs in seven European cities spread across six countries (Oristano – Italy, La Rochelle and Shopia-Antipolis – France, Lausanne – Switzerland, Vantaa – Finland, Trikala – Greece, and San Sebastian – Spain). The general objectives included the study of long term socio-economic impacts of automated mobility; and the definition of a legal framework to allow AVCTs on urban roads (Alessandrini, 2018). The project covered more than 25,000 km driven by the autonomous shuttles (provided by EasyMile and Robosoft) and carried over 60,000 passengers, being (to date) the most extensive trial with AVCTs worldwide (Ainsalu et al., 2018).

Another relevant example of a project placed on stage 1 of on-demand services was the Finnish project SOHJOA that ran from June 2016 to May 2018 (SOHJOA, 2018). The project was the first of its kind to introduce AVCTs in mixed traffic conditions on Finnish roads. The aim was to utilize an enterprise- and area-based approach to create new innovations and understand the use of AVCTs in last-mile transportation for the benefit of both the public sector and companies specializing in IoT and transport services. Trials were carried out on three demonstrator cities (Espoo, Helsinki, and Tamper) carrying passengers over small mixed traffic-looped routes (no longer than 1 km), where the EZ10 shuttles from EasyMile had to face Finland's harsh weather conditions.

Some other relevant examples of stage 1 DRT services and trials with AVCTs were the NAVLY trials in the Confluence district in Lyon – France (Keolis, 2016); the WEpods project in the Dutch cities of Delft and Wageningen (TUDelft, 2016); and the MCITY project in the University of Michigan – United States (MCITY, 2018).

Stage 2 – Fixed Route with on-Demand Stops

Continuing the analysis, stage 2 is equivalent to traditional urban bus services. That is, the AVCT does not need to stop at each stop/station (only upon request by passengers who want to board or alight), and, as in stage 1, it follows a fixed route with fixed operating hours and fixed timetable.

Examples here are not as numerous as on stage 1, but it is worth mentioning the experimental pioneering trial from August to November 2019 in Singapore, where citizens and tourists were able to try an on-demand service with AVCTs in Sentosa Island. Users were able to hail an autonomous shuttle via a mobile app or at the several kiosks along a 5.7 km looped route to bring them to selected destinations on the island (Intelligent Transport, 2019). Besides using two Navya shuttles, the company responsible for deploying the trials – ST Engineering – also deployed two 20-seater converted mini buses. They have combined a variety of technologies, such as radar, lidars, GPS, odometry, and computer vision, to transform a 6.8-metre electric bus into one that is capable of sensing its environment and navigating without human input (ST Engineering, 2019).

In the Baltic sea region, the European Commission funded project Fabulos started testing on April 2020 in a looped-route in streets of Helsinki (Finland), an on-demand service by using GACHA shuttles (provided by the Japanese newcomer MUJI), where users could hail the shuttle by using an app on their phones. The fleet of three vehicles was operated and monitored from a Remote Control Centre

(Fabulos, 2020). The project also includes trials in Tallinn (Estonia) – with a fleet of three ISEAUTO shuttles (developed by Tallinn University of Technology and Auve Tech) and, in Gjesdal (Norway) with a fleet of Navya shuttles.

In Australia, the BusBot project that started in July 2018 allowed users from Coffs Harbour and Marian Grove (a retirement village) to trial EasyMile shuttles with on-demand capabilities through the use of an app where they could hail the service (BusBot, 2019). The future steps predicted for the project are to transport passengers with no preset route (level 3 on Fig. 1.2) by using artificial intelligence to determine the most efficient path between the points on a geo-fenced grid (Rooney, 2019). In 2018, in Paris at Charles-de-Gaulle airport, a 700 meter-long route was put in place by Navya in Partnership with Keolis and the ADP group. The service was accessible to users via a QR code on their smartphones where they were able to hail the shuttle at their convenience (AFF, 2018).

And finally, it is worth recapping the ParkShuttle service offered by 2getthere at the Rivium business park in Rotterdam (Netherlands). Their service falls into stage 2 since, according to the company itself, "it basically operates as a horizontal elevator. The vehicles stop at every station selected as a destination and where transport has been requested. As a consequence it will operate as bus service in peak hours and almost as a DRT system in off-peak hours" (2getthere, 2018).

Stage 3 – Fixed Route with Flexible Detours and on-Demand Stops

On stage 3, the DRT services start to move away from the expected offerings for public transport. That is, the AVCTs would still work as a regular city-bus by following a fixed looped route, and stopping only upon request; however, it can take detours on pre-programmed routes according to users' requests.

To date, no experiments with AVCTs were identified as belonging to stage 3. However, once stage 2 services are well established, it is possible that flexible detour routes to be added to the pre-existing fixed looped route, thus providing users with an extra layer of flexibility to the DRT services offered. However, such route detours may affect the frequency of service and the waiting time of passengers, thus further studies and trials should be conducted to better assess route optimization and service quality.

Stage 4 – Geofenced Flexible Gridded Routes and on-Demand Stops

Arguably the most radical change for the current PTOs business models, stage 4 DRT services, are expected to disrupt the *modus operandi* of public transport as it is. In this stage, the shuttles do not need to follow a fixed looped route nor have fixed stops/stations. They run on a geofenced grid of streets and avenues in a given area and can be hailed via a smartphone app to take users to/from any given points within the grid.

Due to the inherent complexity of this level and the previously mentioned legal and technological constraints that currently permeate AVCTs, real examples involving autonomous shuttles are scarce. However, the following is (to date) the only and most disruptive example of DRT experimentations with AVCTs in place.

In Geneva (Switzerland), the local public transport operator TPG, in partnership with the European Commission funded project AVENUE, has been running a stage

1 fixed route service with AVCTs since 2018 in the Meyrin district (AVENUE, 2020). However, from August 2020, they started to deploy a level 3 on-demand service in the hospital district of Belle-Idée using a fleet of Navya shuttles. With that, they were able to directly jump from stage 1 to stage 4, thereby offering a truly disruptive level of service when compared to the traditional business model of public transport.

The service is the first of its kind with AVCTs and it runs on a geofenced mapped grip of streets with flexible pre-programmed stops and with no fixed frequency. That is, via an application on their phones, users can hail the shuttle to take them to and from any given point in the grid. Users can see in their smartphone application (provided by MobileThinking) where the shuttles are located, and with that they can send a route request. The fleet dispatching software (provided by BestMile), locates the user and indicates which vehicle is available and how long it will take to get it. The software then adapts the route according to requests from other passengers (Hernandez, 2020). According to the project coordinator, Professor Dimitri Konstantas, "this project represents an opportunity for the University Hospitals of Geneva (HUG) to experiment an innovative solution for local transport. However, this implies changing the model of public transport as we know it today." The AVENUE project also implemented trials (all as stage 1) with AVCTs in three other European cities: Lyon, Luxembourg, and Copenhagen.

As observed by the aforementioned example, the premise here is not to offer door-to-door services per se (like an Uber or taxis), but to pick up/drop off users in hubs as close as possible to their points of origin/destination. Thereby shuttles would act as an intermediate transport mode between a regular city bus and a taxi. Due to this high degree of flexibility, this stage of DRT service offers several advantages to users, as well as opens a wide range of possibilities for operators to customize and diversify their service offering (more details on Sect. 1.4).

Stage 5 – Full on-Demand Door-to-Door Smart Public Transport for Smart Cities

By offering fully customizable door-to-door trips from any given point A to B within a fully mapped geofenced smart grid, stage 5 DRT services are the ultimate goal of autonomous on-demand transport, resembling the business models of profit-oriented businesses like taxis or ride-hailing platforms, such as Uber and Lyft.

In fact, these aforementioned companies are also interested in the benefits of vehicle automation. From September 2016 to March 2018, Uber tried autonomous ride-hailing services in Pittsburgh, San Francisco, and Tempe (Hawkins, 2017; Silver, 2018; Tascarella, 2018). Lyft (Uber's main competitor in the U.S.), announced in January 2016 a partnership with GM to help both companies accelerate in the ride-sharing market, as well as in the AVs arena (Kokalitcheva, 2016), in September 2017, they announced a partnership with Ford, adding the company to its list of self-driving car partners (Isaac, 2017), and in March 2018, they partnered with GoMentum Station (an AVs testing site enterprise) to test their self-driving technology (Crum, 2018).

It is also worth highlighting the giant efforts Google's sister company Waymo – leader on self-driving R&D with more than 4 million miles driven (Silver, 2018). In April 2017, they started a trial of a self-driving taxi service in Phoenix, Arizona, where, in December 2018, they launched their first commercial self-driving service called "Waymo One" (Hawkins, 2018). In June 2020, they announced a partnership with Volvo to integrate Waymo's self-driving technology into their vehicles (Silver, 2020).

On the other hand, based on what is currently observed regarding the existing business models for subsidized transport, stage 5 DRT for public transportation services is still in its very early stages. It requires a complete ecosystem and infrastructure of a smart city with widespread V2X and V2V communication as well as common standards (for sensors, lidars, etc) among the involved OEMs, PTOs, and other stakeholders. Thus, to the best of our knowledge, no trials or services with AVCTs were identified for this DRT stage.

However, the flexibility brought by autonomous vehicles can create disruptive and unimagined business alternatives for PTOs, which could eventually turn this stage into a viable attractive business model option. The following session better explores these potential business model alternatives.

1.4 Business Models Opportunities with on-Demand Autonomous Shuttles

With new and innovative business models emerging due to the widespread adoption and popularization of internet connected devices (smartphones, tablets, and wearables), the concept of Mobility-as-a-Service (MaaS) has been gaining ground in recent years. It presents a shift away from the existing ownership-based transport system towards an access-based one (Jittrapirom et al., 2017). By offering customized transport services to fit individual travel needs and requirements, which can be achieved by uniting already existing transport solutions and transport providers, including public transport, taxi, car and bike sharing, etc., and offering them in subscription packages to customers via a single interface of a service provider (Karlsson Sochor & Strömberg, 2016).

1.4.1 AVCTs as a Transport Mode Within MaaS Offerings

AVCTs may play a very important role within this new MaaS mobility paradigm. According to Anderson (2017), MaaS offers a very good launch pad for autonomous mobility. For the author, "by 2030, 95% of passenger miles travelled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals." Thus, by having the option of being on-demand, and being integrated in a multimodal and customizable business offer, AVCTs can offer a much higher value proposition to users than simply transporting passengers from point A to B. Not to mention that AVCTs are capable of being operational 24/7 (except for the time needed for the recharging of batteries and eventual repairs and maintenance).

As exemplified by Mira-Bonnardel (2021), during peak-hours (from 6 to 9 a.m. and from 5 to 8 p.m.) the shuttles can be used for predetermined journeys with regular schedule and fixed-stops by (for instance) taking commuters to and from their neighborhoods to trunk-lines or by taking children to/from schools (thus being within levels 0 and 1 proposed on Fig. 1.2). However, in off-peak hours (from 9 a.m. to 5 p.m. and from 8 p.m. to 6 a.m.), they can be used for several tailor-made journeys upon request (fitting the proposed levels 3 and 4).

During these off-peak times, AVCTs could be used for transportation of goods (last mile) in city centers for retailers and individuals, transportation for targeted user-groups (people with reduced mobility, leisure centers, care centers, etc.), transportation for city tours and outings, and even night transportation for specific and emergency requests (as a night bus for people returning home from bars and parties, for emergency transport of injured or sick people, specific delivery of goods, etc.) (Mira-Bonnardel, 2021).

In fact, a real example of the potential of AVCTs for goods and cargo transport occurred during the 2020 COVID-19 pandemic. The AVs startup Beep in partnership with Navya used four driverless shuttles to transport coronavirus tests around the Mayo Clinic campus in Jacksonville, Florida (Chitkara, 2020). According to the author, because the routes were isolated from public traffic, the shuttles could be operated without a human safety driver, limiting human exposure to the lab samples.

On the other hand, the pandemic has brought up an important issue to be considered by PTOs for future operations with AVs. As stated by Chitkara (2020), operators will need to ensure that the vehicles are clean between rides, because without proper regular cleaning, users would still be at risk of contracting an illness even if they were alone in the vehicle. Although not perfect solutions, besides the use of face masks, giving users disinfectant wipes or using germ-resistant materials for vehicle interiors could limit the risk of infection.

1.4.2 Advantages of on-Demand AVCTs for Public Transport

Besides the aforementioned alternative business models that on-demand AVCTs can provide to users, operators, and the local communities, they are also capable of addressing some historical challenges faced by PTOs, such as:

First- and Last-Mile Issues

First- and last-mile services (or feeder services) are a well-known issue in the user journey for a range of reasons: low frequency of buses, poor route design, long distance from home to a stop, etc. Thus, passengers may opt to switch to other non-public transport modes, such as driving their private car to a train station and interchanging, using private car-sharing or car-pooling options, etc.

On-demand AVCTs could address the first- and last-mile issue by providing an alternative (or even substitute) to the current public transport network. By not needing a driver, shuttles could run more frequently and use route optimization algorithms to deliver users as close as possible to their destination (e.g., a nearby street corner, a railway station or a bus stop).

Underserved Communities

Many passengers are unable to access public transport either by residing distantly and having no public transport serving their communities, or by the fact that public transport can be perceived as inaccessible for certain groups, such as people with reduced mobility, the elderly, etc.

By not necessarily following fixed routes, AVCTs can serve more isolated communities and provide them with a connection to the existing transportation network. For mobility-impaired and elderly passengers, AVCTs can pick them up from their doors (or close by), thus avoiding their way to the local bus stop, or even avoiding their dependence on others to take them to places.

Incoherent Transfers and Connections

Although feeder services often try to synchronize with trunk lines, their frequency (and data availability to users) may not allow complete and seamless synchronization with all services, which can result in very long waiting times for passengers.

With the growing number of Mobility-as-a-Service (MaaS) schemes and fleet orchestration algorithms, AVCTs are able to be scheduled in real time and users have the convenience of following the updates of the service arrival instantly on their smartphones. Although waiting times would still exist, their average is likely to be lower than traditional first- and last-mile services.

Unnecessary Trips

To comply with citizens' right to travel in their local communities, PTOs must offer routes that are often inefficient and have low frequency of use, thus creating unnecessary expenses with fuel, maintenance, and salaries.

By the use of fleet orchestration and mapping algorithms, AVCTs can remain stationary until they are needed, and then can be directed to the right location with optimal timing and routing and also inform users of the most efficient pick-up and drop-off points. In addition, by not needing a driver, crew costs are already a savings for the PTO, and by being able to idle the operator can also save on maintenance and energy costs. Overall, operating costs can be significantly reduced with DRT autonomous shuttles.

In order for all these aforementioned solutions to work, there are still many open questions to be answered. As posited by Barrett et al. (2019), should pricing be the same as existing public transport fares? Traditional subsidy models are not suited for on-demand; therefore, how should they be managed? Should DRT be contracted as a subset of mass transport or separately with a different set of providers? Should private ride-hailing operators be able to participate in the market? How do existing regulations about vehicles, autonomous driving, accessibility requirements, children as passengers, etc. need to evolve to meet DRT service offerings? And finally, how will conventional PTOs evolve into on-demand providers, or will newcomers be better suited to provide these services?

Therefore, PTOs and public authorities should have clearly provided coherent answers to these questions as well as have their objectives and goals strategically aligned as a way of providing adequate conditions for a full scale deployment of these services.

1.5 Concluding Remarks

By providing a holistic overview of the evolution of automation in public transport, this introductory chapter raises awareness towards the relevance and benefits that automation can bring to public transport offerings. Not only by reducing operating costs for the PTOs but also by providing a wide range of flexible stages of on-demand services capable of meeting the most diverse demands of people's mobility.

In this sense, vehicular automation itself is not a novelty and it is not disruptive; it is an evolution composed of incremental leaps over time. What makes autonomous shuttles for collective transport revolutionary are the new and innovative business model ecosystems enabled by on-demand services as well as the revolution in usage forms, and the inherent changes on the relationships between citizens, mobility solutions, and the cities.

As business models change, new opportunities will arrive for public transport, changing its economic profile along with it. By, for instance, relying less on subsidies and more on private revenue sources (as better detailed on Chaps. 4, 8, and 9). Furthermore, these diverse business model offerings will be able to better answer the diverse needs of users by offering customized solutions (as shown in Chaps. 6 and 7). On the other hand, this revolution in public transport will also raise the need for new governance models (as shown in Chap. 10), as well as adapted and flexible legislations (described in Chaps. 2 and 3).

Thus, on-demand services are increasingly seen as enabling better delivery and more-efficient public transport (as described in Chap. 5) and, once linked to autonomous mobility, it truly has the potential to disrupt the business model of urban transport as we know it.

Acknowledgments This research has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 769033 (AVENUE project).

References

2getthere. (2018). *Autonomous vehicle systems for smart cities*. [2getthere company website]. Retrieved on July 29, 2020, from: https://www.2getthere.eu

Abe, R. (2019). Introducing autonomous buses and taxis: Quantifying the potential benefits in Japanese transportation systems. *Transportation Research Part A: Policy and Practice, 126*, 94–113.

AFF. (2018). L'aéroport de Paris Roissy test les navettes autonomes Navya. *AFF /// ACTU-AERO.FR*. Retrieved on August 3, 2020, from: https://actu-aero.fr/2018/04/06/laeroport-de-paris-roissy-test-les-navettes-autonomes-navya/

Ainsalu, J., et al. (2018). State of the art of automated buses. *Sustainability, 10*(3118), 2–34.

Alessandrini, A. (2018). *Implementing automated road transport systems in urban settings* (1st ed.). Amsterdam: Elsevier.

Anderson, M. (2017). RethinkX: Self-driving electric cars will dominate roads by 2030. *IEEE Spectrum*. Retrieved on July 29, 2020, from: https://spectrum.ieee.org/cars-that-think/transportation/self-driving/rethinkx-selfdriving-electric-cars-will-dominate-roads-by-2030

Antonialli, F. (2019). *Business platforms for automated driving systems: A product-service system approach for mobility as a service*. PhD thesis Universidade Federal de Lavras, 189p.

Antonialli, F. (2021). Autonomous shuttles for collective transport: a wordwide benchmark. *International Journal of Automotive Technology and Management, 21*(1/2), 5–28.

Attias, D. (2017). The automobile world in a state of change: from the automobile to the concept of auto-mobility. In D. Attias (Ed.), *The automobile revolution: Towards a new electro-mobility paradigm* (1st ed.). Gewerbestrasse, Switzerland: Springer.

AVENUE Project. (2020). Geneva site description. *AVENUE H2020*. Retrieved on August 3, 2020, from: https://h2020-avenue.eu/portfolio-item/geneva/

Barrett, S., Santha, N., & Khanna, A. (2019). On-demand public transport: Key learnings from global pilots. *L.E.K. Special Report*. Retrieved on July 29, 2020, from: https://www.lek.com/sites/default/files/insights/pdf-attachments/On-demand-public-transport.pdf

BusBot. (2019). Three phase trial. *Busbot*. Retrieved on July 29, 2020, from: https://www.busbot.com.au/three-phase-trial/

Chitkara, H. (2020). Self-driving startups Beep and Navya explore driverless transport for coronavirus lab specimens. *Business Insider France*. Retrieved on July 29, 2020, from: https://www.businessinsider.fr/us/beep-navya-explore-self-driving-coronavirus-lab-specimen-delivery-2020-4

Crum, R. (2018). Lyft's self-driving technology finds momentum in Concord. *The Mercury News*. Retrieved on July 29, 2020, from: https://www.mercurynews.com/2018/03/08/lyfts-self-driving-technology-finds-momentum-in-concord/

Day, J. R., & Reed, J. (2011). *Story of London's underground* (11th ed.). Capital Transport Publishing, 224p.

Druker, S., & Nassar, H. M. (2016). Evergreen extension opening today. *News 1130*. Retrieved on August 3, 2020, from: https://www.citynews1130.com/2016/12/02/evergreen-extension-opening-today/

Enoch, M. P. (2015). How a rapid modal convergence into a universal automated taxi service could be the future for local passenger transport. *Technology Analysis & Strategic Management, 27*(8), 910–924.

Fabulos Project. (2020). Helsinki Pilot. *Fabulos*. Retrieved on July 29, 2020, from: https://fabulos.eu/helsinki-pilot/

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice, 77*, 167–181.

Fagnant, D. J., & Kockelman, K. M. (2018). Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. *Transportation, 45*(1), 143–158.

Fluhr, D. (2017). Navya vs EasyMile – Who will conquer the Autonomous E-Shuttle Market? *Smart Mobility Hub*. Retrieved on September, 30, 2018, from: http://smart-mobility-hub.com/navya-vs-easymile-who-will-conquer-the-autonomous-e-shuttle-market/

Gandia, R. M., Antonialli, F., Cavazza, B. H., Neto, A. M., Lima, D. A., Sugano, J., et al. (2018). Autonomous vehicles: Scientometric and bibliometric review. *Transport Reviews, 38*, 1–20.

Harris, R. (2018). Shuttle diplomacy: The path to deployment. *Transportation as a Service Magazine*. Retrieved on July 29, 2020, from: https://www.publishing.ninja/V4/page/4572/245/270/1

Hawkins, A. J. (2017). Uber's self-driving cars are now picking up passengers in Arizona. *The Verge*. Retrieved on August 3, 2020, from: https://www.theverge.com/2017/2/21/14687346/uber-self-driving-car-arizona-pilot-ducey-california

Hawkins, A. J. (2018). Riding in waymo one, the Google spinoff's first self-driving taxi service. *The Verge*. Retrieved on July 29, 2020, from: https://www.theverge.com/2018/12/5/18126103/waymo-one-self-driving-taxi-service-ride-safety-alphabet-cost-app

Hernandez, M. (2020). Genève va tester cet été des navettes autonomes sur demande. *AVENUE H2020*. Retrieved on July 29, 2020, from: https://h2020-avenue.eu/wp-content/uploads/2020/06/20200619-Radio-Lac-Vehicules-automatises.pdf

Iclodean, C., Cordos, N., & Varga, B. O. (2020). Autonomous shuttle bus for public transportation: A review. *Energies, 13*(11), 1–45.

Intelligent Transport. (2019). Singapore's first on-demand autonomous shuttle trial opens to the public. *Intelligent Transport*. Retrieved on July 29, 2020, from: https://www.intelligenttransport.com/transport-news/86331/first-on-demand-autonomous-shuttle-trial/

Isaac, M. (2017). Lyft adds Ford to its list of self-driving car partners. *The New York Times*. Retrieved on July 29, 2020, from: https://www.nytimes.com/2017/09/27/technology/lyft-ford-self-driving-cars.html

Jansson, J. O. (1980). A simple bus line model for optimization of service frequency and bus size. *Journal of Transport Economics and Policy, 14*(1), 53–80.

Jittrapirom, P., Caiati, V., Feneri, A., Ebrahimigharehbaghi, S., Alonso-González, M. J., & Narayan, J. (2017). Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges. *Urban Planning, 2*(2), 13–25.

Karlsson, I. C.M., Sochor, J., Str mberg, H. (2016). Developing the "Service" in Mobility as a Service: experiences from a field trial of an innovative travel brokerage. *Transportation Research Procedia, 14*, 3265–3273.

Keolis. (2016). Navly, la première desserte de transport public par navette électrique autonome. *Keolis Actualités*. Retrieved on August 3, 2020, from: https://www.keolis.com/fr/medias/newsroom/actualites/navly-navette-electrique-autonome-conquiert-lyon

Kokalitcheva, K. (2016). GM and Lyft will test self-driving taxis within the next year. *Fortune*. Retrieved on August 3 2020, from: http://fortune.com/2016/05/05/lyft-gm-self-driving-pilot/

Lambert, S., & Granath, E. (2020). Will production cars ever reach Autonomy Level 5? *Intelligent Mobility XPerience*. Retrieved on July 29, 2020, from: https://www.intelligent-mobility-xperience.com/will-production-cars-ever-reach-autonomy-level-5-a-910884/

Lima, D. A. (2015). *Sensor-based navigation applied to intelligent electric vehicles*. Doctoral thesis, Université De Technologie De Compiegne, Compiegne, France.

Mcity. (2018). Mcity driverless shuttle launches on U-M's north campus. *Mcity News & Events*, Retrieved on August 3, 2020, from: https://mcity.umich.edu/mcity-driverless-shuttle-launches-on-u-ms-north-campus/

Merat, N., Madigan, R., & Nordhoff, S. (2017). Human factors, user requirements, and user acceptance of ride-sharing in automated vehicles. (International Transport Forum – discussion paper). Retrieved on August 3, 2020, from: https://www.google.com.br/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=2ahUKEwi97onnuPXhAhWjAmMBHV0vANoQFjABegQIBBAC&url=https%3A%2F%2Fwww.itf-oecd.org%2Ffile%2F16355%2Fdownload%3Ftoken%3DwzML3Ngi&usg=AOvVaw3u20zlsLVA-aIGHQmK0810

Mira-Bonnardel, S. (2021). Robomobility for collective transport: a prospective user centric view. *International Journal of Automotive Technology and Management, 21*(1/2), 99–120.

Mira-Bonnardel, S., & Attias, D. (2018). The autonomous vehicle for urban collective transport: Disrupting business models embedded in the smart city revolution. In *Proceedings of International Colloquium of Gerpisa: Who drives the change? New and traditional players in the global automotive sector*. São Paulo, 26.

Mulley, C., Nelson, J., Teal, R., & Wright, S. (2012). Barriers to implementing flexible transport services: An international comparison of the experiences in Australia, Europe and USA. *Research in Transportation Business & Management, 3*, 3–11.

Ongel, A., Loewer, E., Roemer, F., Sethuraman, G., Chang, F., & Lienkamp, M. (2019). Economic assessment of autonomous electric microtransit vehicles. *Sustainability, 11*(3), 1–18.

Pakusch, C., & Bossauer, P. (2017). User acceptance of fully autonomous public transport. In *ICE-B*, pp. 52–60.

Pakusch, C., Stevens, G., Boden, A., & Bossauer, P. (2018). Unintended effects of autonomous driving: A study on mobility preferences in the future. *Sustainability, 10*(7), 2404–2426.

Pettersson, F. (2019). An international review of experiences from on-demand public transport services. *The Swedish Knowledge Centre for Public Transport*. Retrieved on August 3, 2020, from: http://www.k2centrum.se/international-review-experiences-demand-public-transport-services

Poorsartep, M. (2014). Self-driving cars: Radical innovation in the transportation industry. In B. Christiansen, S. Yildiz, & E. Yildiz (Eds.), *Transcultural marketing for incremental and radical innovation* (1st ed.). Hersey, Pennsylvania: IGIGlobal.

Rooney, K. (2019). This driverless shuttle bus is picking up elderly Australians on demand. *World Economic Forum*. Retrieved on August 3, 2020, from: https://www.weforum.org/agenda/2019/09/autonomous-vehicle-mobility-elderly-emissions/

Schellekens, M. (2015). Self-driving cars and the chilling effect of liability law. *Computer Law & Security Review, 31*(4), 506–517.

Schwab, K. (2017). *The fourth industrial revolution*. London: Penguin.

Silver, D. (2018). *Self-driving cars: Miles driven*. (Medium Corporation report). Retrieved on August 3, 2020, from: https://medium.com/self-driving-cars/miles-driven-677bda21b0f7

Silver, D. (2020). Waymo and Volvo form exclusive self-driving partnership. *Forbes*. Retrieved on July 28, 2020, from: https://www.forbes.com/sites/davidsilver/2020/06/29/waymo-and-volvo-form-exclusive-self-driving-partnership/#7328a41c6adf

Society of Automotive Engineers [SAE]. (2016). *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles J3016_201609*, Society of Automotive Engineers. Retrieved on August 3, 2020, from: https://www.sae.org/standards/content/j3016_201609/

SOHJOA Project. (2018). *SOHJOA-projektin materiaalia*. Retrieved on July 29, 2020, from: https://www.sohjoa.fi/materiaalia

ST Engineering. (2019). On-road Testing of Autonomous Shuttles Begins at Sentosa. *ST Engineering News Releases*. Retrieved on July 29, 2020, from: https://www.stengg.com/en/newsroom/news-releases/on-road-testing-of-autonomous-shuttles-begins-at-sentosa/

Tascarella, P. (2018). Uber debuts self-driving cars for Pittsburgh customers. *Pittsburgh Business Times*. Retrieved on August 3, 2020, from: https://www.bizjournals.com/pittsburgh/news/2016/09/14/uber-debuts-self-driving-cars-for-pittsburgh.html

Tirachini, A., & Antoniou, C. (2020). The economics of automated public transport: Effects on operator cost, travel time, fare and subsidy. *Economics of Transportation, 21*, 1–15.

TUDelft. (2016). WEpod autonomous vehicles operate as temporary bus service. *Delft University of Technology*. Retrieved on July 27, 2020, from: https://www.tudelft.nl/en/2016/tu-delft/wepod-autonomous-vehicles-operate-as-temporary-bus-service/

Union Internationale des Transport Publics [UITP]. (2011). Metro automation facts, figures and trends. *UITP Press Kit*. Retrieved on July 27, 2020, from: https://www.uitp.org/sites/default/files/Metro%20automation%20-%20facts%20and%20figures.pdf

Viegas, J. (2017). Automation and the future of public transport. *Intelligent Transport*. Retrieved on July 27, 2020, from: https://www.intelligenttransport.com/transport-articles/72914/automation-future-public-transport/

Winter, K. (2015). *Development and application of a method to design a demand-responsive service operated by fully automated vehicles*. Master's thesis, Delft University of Technology, Delft, Netherlands.

Chapter 2
Evolution of Government Policy for Autonomous Mobility: Korean and French Cases and Their Differences

Jeehoon Ki

Abstract Government behavior is one of the key factors shaping the coming era of autonomous mobility. This chapter explores the evolution of government policy and regulations in the 2010s for the commercial deployment of autonomous vehicles (AVs). This study explores the cases of Korea and France as they are major players in the global automotive industry and, at the same time, take contrasting approaches to the emergence of autonomous mobility. They have in common that AVs were set as a national strategic sector in the early 2010s for industrial competitiveness. Various policy measures and regulation changes have been followed in four areas: (1) research and development (R&D) and tests, (2) legal and regulatory framework, (3) infrastructure for AV deployment, and (4) social acceptance. The two countries take different approaches. While France takes a demand-pull approach, focusing on developing autonomous *mobility*, Korea takes a tech-push approach, focusing on developing autonomous *vehicles*. This difference reflects each country's country-specific socio-economic context and their government's perspective on autonomous driving.

Keywords Autonomous vehicle · Mobility · Government policy · Legislation · Korea · France

---

This chapter is an adaptation of the author's original study, Ki (2020), which was supported by Fondation France-Japan of the EHESS – Renault Chair.

J. Ki (✉)
KISTEP, Wonjung-ro, Maengdong-myeon, Eumseong-gun, Chungcheongbuk-do, Republic of Korea
e-mail: jki@kistep.re.kr

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_2

2.1 Introduction

Autonomous mobility is expected to transform the automotive industry, the transportation system, and eventually our way of life. Since the 2010s, governments in many countries have been implementing national policies for the development and deployment of autonomous vehicles (AVs) to embrace this extensive transformation. Government policies are instrumental in socio-economic transformation by technological innovation because they tend to serve as the initial *rules of the game* that affect the practices and behavior of consumers, producers, and intermediaries in relevant sectors. This chapter aims to explore the development of the national AV initiatives and policy measures of Korea and France in the 2010s. Specific questions include: (1) When did the two countries start formulating national initiatives for AVs? (2) What are their major policy measures and how to categorize them? (3) Are there any similarities and differences between Korea and France? Both qualitative and quantitative analyses are employed to address these questions.

Given that government policy affects the practices and behavior of actors in relevant sectors, answers to these questions can contribute to an in-depth understanding of how and why these countries follow their own trajectories of socio-economic transformation, which in turn can help in formulating subsequent policy actions and business strategies in the public and private sectors, respectively, in the coming era of autonomous mobility.

A comparative analysis provides a deeper understanding of AV policies than a single case study. The similarities may shed light on essential ingredients for a country's AV policy. The differences can indicate the uniqueness of the respective countries' AV policies, reflecting their country-specific context of society, governance, industry, and so on. The cases of Korea and France are selected as the two countries are active in upgrading their transport systems and have large automotive industries with global OEMs, such as Hyundai, Kia, Renault, and PSA. More interestingly, the two countries have been taking contrasting approaches in AV policy. The evolution of their policies for commercial AV deployment can be a useful reference to other countries, especially for latecomers to this sector when they formulate their own AV policies.

Sections 2.2 and 2.3 elaborate the evolution of AV policies of Korea and France, respectively. Sect. 2.4 highlights the differences between the two countries' AV policies by a bibliometric analysis. Finally, Sect. 2.5 summarizes findings of this study.

2.2 South Korean AV Policy

2.2.1 Evolution of the Korean AV Policies

The evolution of the Korean government's AV policy in the 2010s can be divided into four stages: (1) recognition phase (2012); (2) selection phase (2013–2014); (3) planning phase (2015–2016); and (4) acceleration phase (2017–2021). Each phase is described in the following sub-sections.

2.2.1.1 Recognition Phase (2012)

In 2012, the South Korean government started to recognize AV development as a policy task. In June 2012, the Ministry of Land, Infrastructure, and Transport (MOLIT), a ministry charged with transport and logistics in Korea, announced the first Master Plan for Motor Vehicle Policy (2012–2016). The Master Plan for Motor Vehicle Policy shall, by law, include the development prospects of the automotive technology, the orientation of the vehicle management and safety policies, and matters on vehicle R&D to manage motor vehicles and increase their safety efficiently. The 1st Master Plan included autonomous driving (AD) as a subtopic of the development of convergence of vehicles and information technology (IT). This plan is the first major government policy in Korea to address AV development as a policy task.

Three months later, in September 2012, AV development was included again in another major policy, entitled Promotion Strategy for IT Convergence (2013–2017). The five-year inter-ministerial strategy proposes the development of AVs and cooperative intelligent transport systems (C-ITS) as policy actions to promote convergence between IT and other fields. In this strategy, AV development was a subtopic of the development of vehicles and IT convergence. In the above-mentioned two policies, AV development is not a main policy task but a subtask of the other R&D tasks, suggesting that AVs are an emerging but incipient topic in formulating government policies in Korea in 2012.

2.2.1.2 Selection Phase (2013–2014)

In 2013–2014, the AD technology was selected as a strategic field at the sectoral and national levels. Formulated jointly by relevant ministries, the 3rd Master Plan for Science and Technology (2013–2017), announced in July 2013, selected 120 national strategic technologies, in which C-ITS was included. In October 2013, the Ministry of Science and ICT (MSIT) announced the Mid- and Long-term R&D Strategy for ICT (2013–2017), which selected autonomous mobility service as one of the 15 future services. Two months later, in December 2013, the Ministry of Trade, Industry, and Energy (MOTIE), a ministry charged with the industries in Korea, announced one of its highest-level plans, entitled the 6th Plan for Innovation of Industrial Technology (2014–2018). The plan chose 13 fields, in which the Ministry will run large-scale R&D programs for the next 5 years, and AD technology was included.

A substantial difference between 2012 and 2013 can be observed in the government plans for AV development. Although the 2012 policies deal with AV development as a subtask of other R&D tasks, the 2013 policies treat it as a major policy task of the Korean government.

In March 2014, AV development became a national-level strategic task because the inter-ministerial industrial growth strategy called Future Growth Engines (Future GE) was announced with 13 selected strategic fields. This selection means that massive government R&D investment and supportive regulatory changes will be implemented by relevant ministries to promote the growth of the selected fields. Selected as one of them, *smart cars* mainly means AVs, including connected vehicles, C-ITS, and V2X communication technologies.

2.2.1.3 Planning Phase (2015–2016)

By 2015, the Korean government established detailed action plans for AV development and deployment. In March 2015, the Comprehensive Action Plan (CAP) of Future Growth Engines was announced. The CAP consists of the policy roadmaps and detailed policy tasks mainly in terms of R&D, infrastructure, regulatory framework, and international harmonization for the 13 strategic fields, including smart cars, of the Future GE initiative, announced a year ago. The Future GE initiative is basically an R&D plan; thus, the CAP of Future GE focuses on planning R&D investment in AV parts and technologies while other subjects such as infrastructure, regulatory framework, and international harmonization are addressed with less focus.

A seminal plan in Korean AV policy was announced 3 months later, in June 2015. Headed by the MOLIT, relevant ministries jointly announced the Plan to Support AV Commercialization. Not giving too much importance to R&D, this plan contains multifarious policy actions to prepare the future commercial deployment of AVs. The policy actions include establishing legal and regulatory frameworks for AV tests and deployment, R&D investment, building AV test facilities, and road and digital infrastructure for AV deployment. More importantly, the Korean government's goals on AV deployment was first revealed in this plan: Level 3 AVs in use on roads by 2020, Level 4+ infrastructure by 2022, and eventually Level 4+ AV deployment by 2030.

2.2.1.4 Acceleration Phase (2017–2021)

President Moon Jae-in's five-year term administration, which began in 2017, reaffirmed AVs as a national strategic field. The administration's Growth Engine (GE) initiative, which was announced in December 2017 and entitled Innovative Growth

Engine (Innovative GE), selected 13 national strategic fields, including AVs, for Korea's future industrial competitiveness. The other fields include AI, renewable energy, personalized healthcare, and drones. The AV was a subfield of the smart car in the previous administration's GE initiative. This time, AV, which replaced the smart car, became an independent national strategic field.

Three months later, in February 2018, the Korean government proclaimed two plans regarding AVs at the same event. First, MOTIE announced a growth plan for the automotive industry entitled Future Car Industry Development Strategy, which was jointly established by relevant ministries. The strategy addressed two new paradigms, namely, electric vehicles (EVs) and AVs, in the automotive industry. In the plan, the part for AVs addresses policy actions to promote future AV deployment, which is an update of the Plan to Support the Commercialization of AVs announced in June 2015, for reflecting development in AV technology and the government policy since then. The MOLIT announced the Plan to Establish Smart Transport Systems, which is an action scheme of the MOLIT in their policy areas, responding to the AV part of the Future Car Industry Development Strategy. The MOLIT's policy tasks presented in the Plan to Establish Smart Transport Systems include:

- Building test facilities for AV development
- Establishing C-ITS, road infrastructure, and high-definition (HD) maps for future AV deployment
- Organizing a public-private consultative committee to support the industrial ecosystem of connected and autonomous vehicles (CAVs)
- Implementing AV pilots and trials to increase the public acceptance of AVs

In October 2019, the relevant ministries jointly declared an elaborated version of the Future Car Industry Development Strategy with a slight change in its name to Future Car Industry Development Strategy 2030. The strategy outlines policy tasks to leap into a leading country in the future automotive industry by 2030. The strategy also includes a revision on AV deployment targets, given that the AV technology advances slower than the previous expectations. Table 2.1 summarizes the development of the Korean AV polices in the 2010s and its four phases.

Over the evolution of the four phases, government actions have surged since 2015 when the third phase (or the *planning phase*) started. The amount of government spending on AV R&D has rapidly increased since 2015; such spending was gradually increased before 2015 (Fig. 2.1a). The share of the expenditure on AV development in the total R&D budget also presents the same trend, indicating that the trend in the amount of AV R&D spending is not caused by the increase in total R&D spending of the Korean government. Although AVs were selected multiple times as a national strategic item since 2013, or the second phase, securing R&D budget for AVs required some time given the government budgeting process. Accordingly, the surge in AV R&D spending occurred approximately one or two years later in 2015.

Figure 2.1b presents the trend of the number of news articles that contain words "AV" and "government" in Korean in their title or body texts. Not precise though, this number roughly suggests the involvement of the Korea government in the topic of

Table 2.1 Development of Korean AV policies in the 2010s

Phase	Date	Policy/Plan	Ministry in charge[a, b]	Remarks
Recognition	Jun 2012	1st Master Plan for Motor Vehicle Policy (2012–2016)	MLTM	A minor focus on AV as an R&D subject
	Sep 2012	Promotion Strategy for IT Convergence (2013–2017)	Relevant ministries (MKE)	AV mentioned as a form of convergence of IT and auto
Selection	Jul 2013	3rd Master Plan for Science and Technology (2013–2017)	Relevant ministries (MSIP)	120 natl. strategic tech. (incl. smart cars)
	Oct 2013	ICT R&D Mid- and Long-term Strategy (2013–2017)	MSIP	15 future IT service (incl. driverless transport)
	Dec 2013	6th Plan for Innovation of Industrial Technology (2014–2018)	MOTIE	13 fields of tech dev. (incl. AVs)
	Mar 2014	Future Growth Engines	Relevant ministries (MSIP)	13 strategic fields. (incl. smart cars)
	July 2014	Mid- and Long-term R&D Strategy for Land, Infrastructure, and Transport (2014–2023)	MOLIT	10 strategic R&D fields (incl. smart roads)
Planning	Mar 2015	Comprehensive Action Plan for Future Growth Engines	Relevant ministries (MSIP)	Detailed R&D plans
	May 2015	Plan to Support the Commercialization of Autonomous Vehicles	Relevant ministries (MOLIT)	"Package" of policy tasks
Acceleration & Expansion	Feb. 2017	2nd Master Plan for Motor Vehicle Policy (2017–2021)	MOLIT	
	Dec 2017	Innovation Growth Engines	Relevant ministries (MSIT)	AV, reaffirmed as a strategic field
	Feb 2018	Future Car Industry Development Strategy	Relevant ministries (MOTIE)	Updated AV action plan
		Plan to Establish Smart Transport Systems	MOLIT	Plan for infrastructure and C-ITS
	June 2018	Comprehensive Plan for Research and Development of Land, Infrastructure and Transportation (2018–2027)	MOLIT	8 strategic R&D fields (incl. CAVs)
	Oct 2019	Future Car Industry Development Strategy 2030	Relevant ministries (MOTIE)	Revised roadmap to 2030

[a]The ministry in the parentheses following "Relevant ministries" refers to the leading ministry
[b]*MLTM* Ministry of Land, Transport and Maritime Affairs (now MOLIT), *MKE* Ministry of Knowledge Economy (now MOTIE), *MSIP* Ministry of Science, ICT and Future Planning (now MSIT)

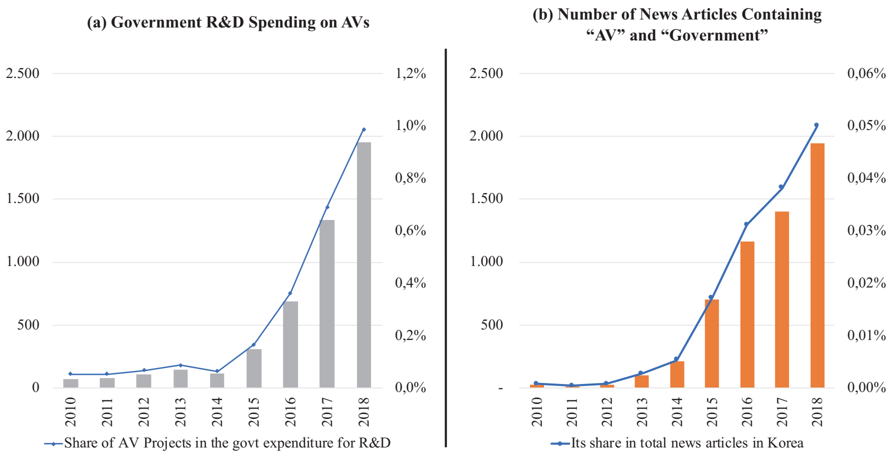


Fig. 2.1 Government R&D Spending on AVs and News Articles containing "AV" and "Government"
Note. Author's visualization using search results from National Science & Technology Information Service (www.ntis.go.kr) (left) and Big Kinds (www.bigkinds.or.kr) (right)

AVs.[1] Although these articles are not limited to articles on the government's AV R&D, their trend is similar to that of the government's AV R&D spending both in absolute number and its share in the total number of news articles of the respective years.

2.2.2 *Korean Government's Goals in AV Deployment*

As of January 2020, the Korean government has three goals in the deployment of AV. The first goal is to deploy US National Highway Traffic Safety Administration (NHTSA) Level 3 vehicles in 2021 commercially.[2] The second goal is to be the first in the world to complete legal and regulatory framework, transport systems, and infrastructure for NHTSA Level 4 automation on major roads, such as expressways and roads in major cities, by 2024. Lastly, the government plans to roll out the world's first NHTSA Level 4 vehicles in 2027 on major roads commercially. These ambitious goals are set in the latest major AV policy Future Car Industry Development Strategy 2030, which was announced in October 2019.[3]

---

[1] This method does not exclude news articles in which the word "government" means the government of other countries.

[2] The Korean government used NTHSA's levels of automation in its goal setting of AV deployment. NHTSA Level 4 is equivalent to SAE Levels 4 and 5.

[3] As of the end of January 2021, there has been no official changes in these targets. However, in December 2020, Hyundai Motor Company (HMC) announced that it would launch a Level 3 autonomous vehicle from 2022. Given the critical role of HMC in the Korean automotive industry, the author conjectures that the government has delayed the first target, Level 3 commercialization in 2021, internally.

The Korean government's AV deployment goals have evolved since 2015. The Plan to Support AV Commercialization, which was announced in May 2015, aimed to commercialize some features of Level 3 automation in 2020, which was the only goal of the Korean government then. Three years later, the government went one step further. The Future Car Industry Development Strategy, which was announced in February 2018, defined two additional goals: to build transport systems and infrastructure for NHTSA Level 4 automation on expressways by 2022 and launch Level 4 vehicles by 2030 commercially.

In comparison with the goals set in February 2018, the current goals, which were announced in October 2019, differ in three ways. First, the government postpones the commercial rollout of Level 3 vehicles from 2020 to 2021. Second, the establishment of transport systems and infrastructure for Level 4 automation on major roads has been also delayed for 2 years, that is from 2022 to 2024. This delay is due to later-than-expected development of CAV technology. Lastly, the government advanced the goal of Level 4 commercialization by 3 years, that is, from 2030 to 2027. Table 2.2 summarizes these changes.

2.2.3 *Legal and Regulatory Framework*

In November 2018, the government announced a roadmap of regulatory changes for AVs. The joint working group of relevant ministries, companies, and research institutes headed by the Office for Government Policy Coordination under the Prime Minister drew up the roadmap, which the government says is *anticipatory*.

Table 2.2 Changes in the Korean government's Goals for AV deployment

Plan	Plan to Support AV Commercialization (May 2015)	Future Car Industry Development Strategy (February 2018)	Future Car Industry Development Strategy 2030 (October 2019)
2020	Partial Level 3 AVs	Level 3 on expressways	
2021			Level 3 AVs
2022		Transport systems and infra for Level 4 on expressways	
2023			
2024			Legal and regulatory framework, transport systems, and infra for Level 4 on major roads (world's first)
2025			
2026			
2027			Level 4 AVs (world's first)
2028			
2029			
2030		Level 4 AVs	

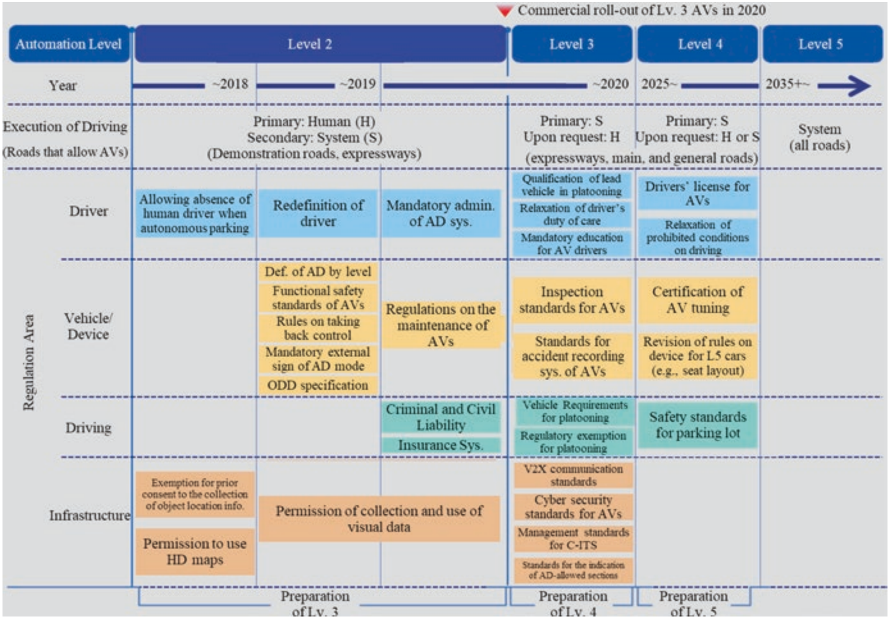


Fig. 2.2 Roadmap of regulatory changes for AVs of the Korean Government (announced in November 2018)
Note. Author's translation of the original diagram in Office for Government Policy Coordination (2018)

Considering the future advancements of the AD system from SAE Levels 2 to 5 and the timing of their arrival, the working group derived eight future AV use cases. Based on these scenarios, the working group identified 30 regulatory issues in four areas and proposed necessary changes in laws and regulations by issue and the time to implement them in advance before problems occur as AVs develop toward Level 5. The four areas correspond to driver, vehicle and device, driving, and infrastructure. For example, the current Road Traffic Act prohibits driving while intoxicated. Level 5 AVs can safely drive when its human driver is intoxicated. Thus, this prohibition has a room to be eased when full automation arrives. The roadmap plans to revise the relevant provisions after 2025 in the era of Level 4 in advance before the next and final automation era arrives. Figure 2.2 presents the summary of the roadmap.

Before the roadmap is established, two changes in the Korean law regarding AVs have been carried out since 2015. The first one is to establish a legal basis for AV tests on the public streets. The other one is to establish a regulatory framework for deployment of AVs in the future. Below are the major changes in the Korean law regarding AVs, which have been carried out by February 2020.

2.2.3.1 Motor Vehicle Management Act

From August 2015 to February 2016, the Motor Vehicle Management Act and its subordinate laws were amended to provide a legal framework for the temporary operation permission system for the AVs. This revision is the first-ever change in the entire Korean law with respect to AVs, thereby creating the definition of AVs in the Korean law for the first time.

In December 2019, the safety standards for *partial* AD systems, equivalent to SAE Level 3, were established through the addition of new provisions to the Rules on Performance and Standards of Motor Vehicles and Their Parts, which is a subordinate law of Motor Vehicle Management Act. The safety standards are not for all but for some features of Level 3 AVs: lane keeping system, driver monitoring system, and reactions to the breakdowns and errors of the Level 3 AD system. AVs with these Level 3 features will be available on the roads from July 2020, when this revision enters into force. This amendment includes the classification of the levels of AD among *partial*, *conditional*, and *full* AD systems, equivalent to SAE Levels 3, 4, and 5. This classification is the first in Korean law.

2.2.3.2 Road Traffic Act

The Road Traffic Act, enacted in 1962, aims to ensure the safe and smooth flow of traffic by preventing and removing all dangers and obstacles to traffic on roads. The main contents of the Act include ways for motor vehicles to pass through roadways, obligations of drivers and employers, and use of roads. The NPA under the Ministry of the Interior and Safety manages the Act. The first revision relating to AVs was made in March 2018. The partial amendment allows a motor vehicle to be equipped with devices for the development of new technology for AVs; these features may disturb the function of traffic law enforcement devices or make it possible to impede safe driving. The regulation that requires the driver to switch off the vehicle when leaving the driver's seat was relaxed to taking measures to prevent traffic accidents when a driver leaves any vehicle, thereby implying that autonomous parking is allowed by law. These two revisions entered into force on the date of the promulgation of the amended Act in March 2018.

2.2.3.3 Act on the Promotion and Support of Commercialization of Autonomous Vehicles (Autonomous Vehicles Act)

The Act was enacted in April 30, 2019 and takes effect a year later (May 1, 2020). This Act provides the legal basis, to name a few:

(a) To enable the MOLIT to formulate a master plan for autonomous-driving-based transport and logistics every 5 years.

(b) To enable the MOLIT to designate *autonomous driving safety areas*, which refers to sections on motorways in which AVs can safely drive. The quality of road infrastructure of the sections should be maintained for AD, and the sections have priority in the installation of C-ITS.
(c) To designate pilot zones for AVs, where various regulatory exemptions are granted to ensure the trials and launching of new business using AVs.
(d) To ease regulations related to information privacy for anonymized personal information and.
(e) To support technological development, manpower cultivation, and international cooperation related to AVs and C-ITS for AD.

2.2.4 Policies for Social Acceptance

Various policy measures are directly and indirectly related to social acceptance. For example, building road infrastructure and institutional frameworks for the AV era contributes to improving public acceptance of AVs. One of the most direct policy measures is AV trial runs that are normally in the form of autonomous shuttles. People can hands-on experience the new technology by taking the autonomous shuttles and sharing roads with them. This section presents the trial runs of autonomous shuttles in Korea.

The first test operation of AVs, which is open to the public, began in September 2018, when the local government of Gyeonggi Province, a Province surrounding Seoul, launched an autonomous shuttle test operation in their smart city entitled Pangyo Zero City.[4] The autonomous shuttle runs a 5.8-km fixed route eight times on weekdays with up to five passengers with a maximum speed of 25 km/h. The shuttle was developed by Advanced Institutes of Convergence Technology (AICT) in collaboration with various automotive and tech companies.[5]

In 2015, with financial support from the central government, the MOLIT, specifically, the Gyeonggi-do Provincial Government, set a plan to build a smart city and provide the above-mentioned autonomous shuttle service within this smart city, which includes a part of the Pangyo Techno Valley. Accordingly, the Provincial Government had its own research institute AICT develop the shuttles. The development of the first unit took 3 years from 2016 to 2018.

Another trial operation was implemented in Daegu Metropolitan City, which has been promoting the AV parts industry. Since August in 2019, French Navya's autonomous shuttles ran a 2.5-km designated section in Daegu at approximately 15 km/h with necessary traffic controls. This test run was not open to the public. The local government originally planned to launch commercial autonomous shuttle services in April 2020 (Ryu, 2020), but it has not been implemented yet as of the end of

[4] Pangyo is the name of a region in Seoung-nam, a city in Gyeonggi-do Province.
[5] Established in 2008, AICT is a research institute financed by Gyeonggi-do Provincial Government.

January 2021. Another local government, Sejong, has a similar plan of autonomous shuttle services; however, Sejong has no trial operation yet. The COVID-19 pandemic seems to affect their rollout plans.

One-time events are being held increasingly, where ordinary people can ride in AVs and shuttles. For example, Pangyo Autonomous Motor Show has been taking place every November since 2017 as of April 2020, hosted by Gyeonggi-do Provincial Government and sponsored by the MOLIT, MSIT, and MOTIE. This event includes AD demonstrations, trial rides, industry fair, and a conference on AV technologies.

Compared with French cases on AV trials, which are addressed in Sect. 2.3.3 for France, AV trials in Korea are less active than France. According to KPMG International Cooperative [KPMG] (2019), the proportion of the national population living in the cities carrying out AV tests are only 2% in Korea versus 21% in France. This indicator reflects an idea that "the more people see AVs on the road, the more comfortable that they are likely to use them when they become available" (KPMG, 2019).

The Future Car Industry Development Strategy 2030, announced in October 2019, contains the government's latest major plan for AV deployment (see Subsection 2.2.1.4 and Table 2.1). The Strategy strengthened policy measures to improve public acceptance of AVs, compared with its previous version, announced in February 2018. First, the central government plans to expand pilot programs of autonomous transportation in various areas in cooperation with local authorities. Specifically, the government is going to supply 50 units of autonomous shuttle busses to cities and towns by 2022, including sparsely populated areas, which are expected to increase mainly due to depopulation. Second, the government plans to develop and pilot public services utilizing autonomous driving technologies from 2021, such as autonomous mass transit, street cleaning cars, autonomous patrol cars, etc. The Strategy reaffirmed that relevant ministries are going to establish a data protection plan for CAV services from 2020.

2.2.5 Implications from Korean AV Policy

A case study on the Korean AV policy leads us to the following implications. First, the evolution of the Korean government's AV policy from 2012 to 2019 shows a *tech-push* approach. Early AV policies around 2012 and 2013 focused on the R&D of AV parts and AD features; then, around 2015, its focus has expanded to promoting tests and establishing digital and road infrastructure and regulatory systems for the future deployment of AVs. Finally, in 2019, AV policies included plans to promote services and applications based on AVs.

Second, the Korean government's AV policy has been established mainly for economic growth and industrial development. The massive R&D funding began in 2015 after Future GE initiative, which was declared in March 2014, selected the AV as one of its 13 strategic fields. The Future GE initiative set the goal of taking the leap toward the top three countries in the future AV industry. The first comprehensive AV plan of the Korean government or the Plan to Support the Commercialization of Autonomous Vehicles states its purpose as to improve traffic safety and create new growth engines by AV deployment. This statement explicitly includes economic purpose. By contrast, social and environmental issues, such as sustainability, urban congestion, and aging society, are seldom addressed at such a top level (e.g., vision, purpose) in major AV policy planning.

Lastly, the Korean AV plans focus more on *commercializing* autonomous car products and components than implementing AV-based services and applications. This tendency is reflected in the fact that, as of the end of February 2020, only one autonomous shuttle test operation has been open to the public since 2015, when the Korean government began to formulate AV policies in earnest.

2.3 French Case of AV Policy

2.3.1 Milestones in AV Policy-Making in France

In September 2013, the French President François Hollande and the Minister of Industrial Renewal Arnaud Montebourg jointly proclaimed the New Industrial France (la Nouvelle France Industrielle, NFI, in French) initiative. The industrial policy aims to build new and competitive industries in France, which will be able to win market share domestically and abroad and thereby create jobs (Organisation for Economic Co-operation and Development [OECD], n.d.). The NFI selected 34 sectors to strategically promote, one of which is driverless vehicles. As a following step, action plans for each were launched in July 2014. Table 2.3 presents the summary of the NFI action plans for AV development. The AV development project in the NFI was headed by Carlos Ghosn, then CEO of the Renault–Nissan–Mitsubishi Alliance.

About a year later, in May 2015, the second phase of the NFI program was launched by Emmanuel Macron, Minister for the Economy, Industry and Digital Affairs. NFI Phase 2 is embodied in the Industry of the Future project, a new matrix for French industrial strategy, which was officially launched by French president Hollande in April 2015 (*La nouvelle France industrielle*, 2017). The project is based on five pillars and is structured around nine industrial solutions. One of the nine solutions is eco-mobility, which includes vehicles that are economical, connected, and autonomous, combined with deployment of relevant infrastructures (*Gouvernement de la République Française*, 2016, p. 76). Meanwhile, in July 2015, a document specifying research objectives of AVs in the NFI was announced.[6] The document aims to achieve the following:

[6]The title of the document is "Objectifs de recherche Nouvelle France Industrielle «Véhicule Autonome»." The document is available at https://pole-moveo.org/wp-content/uploads/2015/07/

Table 2.3 Summary of NFI action plans for AV development

Action	Pilot	Calendar	Finalities/deliverables
1) Coordinate autonomous vehicle initiatives			
Identification and coordination of local initiatives	DGCIS	2015	Pilot areas for the autonomous vehicle
Organization of international cooperation or exchange	DGCIS	2015	Cooperation with China and Korea
2) Demonstrate the socio-economic, safety, and acceptance of the autonomous vehicle			
Study of socio-economic and security impact and acceptability	PFA, Renault Trucks, RATP	2015–2020	Experiments, impact studies, and acceptability studies for targeted use cases
3) Invest in key technological areas of autonomous vehicles			
Launch of targeted R&D projects in the field of embedded intelligence, IHMs, human factors, and connectivity	ITE Vedecom, MEIN	2014	Call for projects dedicated to "autonomous vehicle" (December)
		2015–2018	Launch and realization of R&D projects
4) Demonstrate the improvement in safety by the autonomous vehicle in targeted use cases			
Launch of targeted R&D projects in the field of security	IRT SystemX, MEIN	12/2014	Dedicated project called "autonomous vehicle"
		2015–2018	Launch and realization of R&D projects
		2016	Urban and peri-urban test center
Provision of appropriate test facilities and demonstrations of safety improvement	Test Infrastructure Manager, Builders	2016–2018	Autonomous driving zones
		2015–2018	Tests in real situation on separated pavement, followed by urban and peri-urban sites
5) Develop the regulatory and normative framework with a view to testing and then integrating the autonomous vehicle on the market			
Evolution of the regulatory and normative framework for experimentation and then for integration on the market	Inter-Administration Group (DGEC, DGCIS, DGTIM, DSCR, DAJMEDDE)	Dec, 2014	Regulatory text authorizing open road experimentation
		2015	Proposed standards and regulations for experimentation
		2017/18	French label "safe autonomous vehicle"
		2019	Standards on processes and definition of standards of test rules

(continued)

Table 2.3 (continued)

Action	Pilot	Calendar	Finalities/deliverables
Adaptation of infrastructures based on context	DGITM	2018	Adaptation of necessary infrastructure, excluding connectivity equipment
		2020	Deployment of necessary roadside equipment for connectivity

Note: Translated and adapted from the table on p.14 of La nouvelle France industrielle (2014).

- To present the roadmaps of the use of AVs in areas of private vehicle, industrial vehicle, and public transport systems
- To present the research objectives formalized by these roadmaps in the following fields: embedded intelligence, connectivity, human factors and human-machine interface, and security

In May 2018, Anne-Marie IDRAC, the Senior Head of the National Strategy for the Development of autonomous vehicles, presented the report Development of Autonomous Vehicles – Strategic Orientation for Public Action to the Minister of the Interior, Economy and Finances, and Transport and the Secretary of State for digital affairs (Présentation du rapport, 2018). This report is officially regarded as the French national strategy for AV development of autonomous vehicles of the French government (Les véhicules autonomes, 2020). Addressing the full range of issues regarding AVs, the 96-page report provides "the strategic framework that will structure the French government's policy actions dedicated to the development of automated or driverless vehicles" (Development, 2018, p. 2). The strategic framework has five areas: (1) legislative and regulatory framework; (2) experiments, innovation, and research; (3) digital aspects and data; (4) links to infrastructure, connectivity, and mapping; and (5) economic and societal aspects, governance, and frameworks.

The report set goals of autonomous mobility as follows (Development, 2018, p. 8):

- In 2020:
  - "Supervised autonomous public transport services"
  - "Level-3 automated vehicles in use on roads"
- In 2022:
  - "Level-4 automated vehicles in use on roads"
  - "Development of use cases for logistical operations and automated freight movement"

Objectifs_de_recherche-Veh_Auton_V1.2.pdf

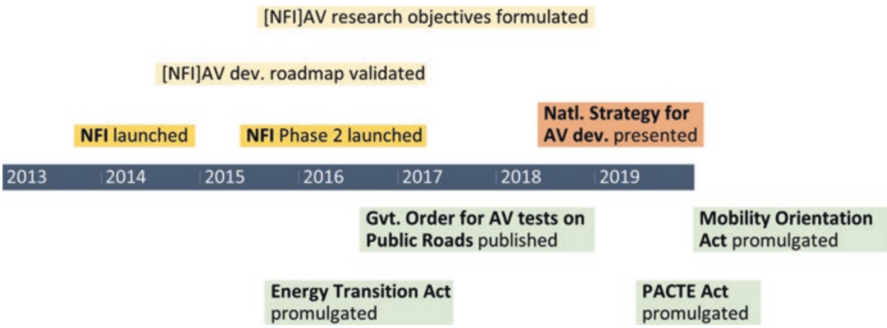


Fig. 2.3 Milestones in Policy-Making and Legislation for AV Development in France

Figure 2.3 summarizes the French government's major policies for the development of AVs. Milestones in legislation in France are also included, which are addressed in the following section.

2.3.2 Key Legislation for AV Development and Deployment

2.3.2.1 Energy Transition for Green Growth Act (LTECV)

The LTECV was enforced in August 2015, following its adoption by the French Parliament in July 2015. This law incorporates "not only matters relating to climate change mitigation, but detailing policy pathways towards low-carbon economic development" (Hölscher & Jensterle, 2018, p. 1). The vast legal document covers eight topics, such as energy efficiency in the building sector, clean transportation, waste management and the circular economy, renewable energies, and so on (Hölscher & Jensterle, 2018, p. 2). As for AVs, LTECV (article 37.IX) provides a legal basis for the test of partial or full AVs on public roads as one of the measures to develop clean transport. As a follow-up, government order no. 2016-1057 on AV experimentation on public roads was published in August 2016.

2.3.2.2 Action Plan for Business Growth and Transformation Plan (PACTE Act)

Following its adoption in April 2019, the PACTE Act was promulgated in May 2019. *PACTE* is officially translated by the French government to Action Plan for Business Growth and Transformation. Heralded as a "new step in France's economic transformation," the PACTE Act "aims to liberate companies from the burden of certain obligations and ensure they are better funded, more innovative and fairer" (Gelpi & Guillemare-Grilo, 2019). Consisting of 221 articles, the act establishes a comprehensive list of measures to achieve the above-mentioned objectives.[7] As a measure to release experiments of companies and thereby to facilitate their innovations, the PACTE Act (article 125) clarifies the experimentation conditions and the criminal liability rules applicable to AVs (Giono, 2019), which introduces the relevant provisions as follows:

The article 125 of the PACTE law amends the ordinance No. 2016-1057 dated August 3, 2016 on the experimentation on public roads of vehicles with driving delegation.

This article specifies the conditions for the experimentation of vehicles with driving delegation. The necessary authorization for the use of vehicles with driving delegation for experimental purposes on the public road is only granted if the driving delegation system can be neutralized or deactivated by the driver at any time. If the driver is located outside the vehicle, he/she must be ready to take control of the vehicle at any time.

The PACTE law specifies that only vehicles with driving delegation used for a public passenger transport service may operate on collective transport lanes. For other vehicles, this possibility is subject to the assent of the competent traffic police authority and of the transport organizing authority.

The PACTE law also clarifies the criminal liability regime applicable to vehicles with driving delegation.

When the vehicle's driving delegation system is activated and operates properly, the driver is not criminally liable for offences that he/she commits in the driving of the vehicle within the meaning of Article L121-1 of the French Highway Code.

However, the driver becomes criminally liable again following the solicitation of the driving system and at the end of a period specified in the experimentation authorization to take back control of the vehicle. The driver is also liable when he/she ignores the obvious circumstance that the conditions for using the driving delegation system were not or no longer met when it was activated.

If the driving of the vehicle, whose driving delegation system is activated, violates rules the breach of which constitutes a contravention, the holder of the authorization shall be financially liable for the payment of fines.

If the driving caused an accident resulting in personal injury, the holder of the authorization shall be criminally liable for the offences of involuntary offence to the life or physical integrity of the person, if a fault is established, within the meaning of Article 121-3 of the French Criminal Code, in the implementation of the driving delegation system (Giono, 2019).

[7] The official website of the French government selectively introduces 10 measures of the PACTE Act. See PACTE (n.d.).

2.3.2.3 Mobility Orientation Act (Loi d'Orientation des Mobilités, LOM)

LOM was published at the end of December 2019, following its adoption in November 2019. The act aims to make everyday transport easier, cheaper, and cleaner (*La loi mobilités*, 2020). The LOM has three pillars (*La loi mobilités*, 2020):

1. To invest more and better in everyday transport
2. To facilitate and encourage the deployment of new mobility solutions for all
3. To initiate the transition to cleaner mobility

The French government targets the deployment of driverless public shuttles from 2020 and Level 4 autonomous private vehicles from 2022 (Development, 2018, p. 8). The act creates the legal framework for this deployment plan. Article 31 of the act empowers the French government to have recourse to an order to take any measure within the domain of law to adapt the legislation to the case of circulation of partial or full AVs on public roads (des Grottes, 2020). Certain provisions of the Highway Code (Code de la route, in French) and on the liability regime are specifically affected (des Grottes, 2020). The act also authorizes the government to issue orders to take any measures to make relevant data from the AV systems accessible to road infrastructure managers, relevant authorities, and so on for various purposes, as specified in the Article 32 of the act.

2.3.3 Autonomous Shuttle Experiments in France

Europe is the most active place in the world for autonomous shuttle experiments for collective transport. Antonialli (2021) identified 176 autonomous shuttle experiments worldwide. Europe holds 101 projects, accounting for more than half of all the 176 ones (see Chap. 1, Fig. 1.1). In Europe, France leads with 29 projects, followed by Germany and Switzerland with 12 and 9, respectively.

The French government has a plan to deploy autonomous shuttles in the public transport system of France (see Subsection 2.3.1.)[8] In areas with few travelers, offering regular bus solutions is not feasible. The French government expects that autonomous shuttles will bring new mobility solutions, particularly in rural areas where they believe autonomous shuttles will be perfectly suited to the small number of travelers. They also plan to use autonomous shuttles for regular lines for a last-mile, for example, between a town center and the nearest station. To accelerate the deployment of these solutions, the government is investing 42 million euros in 16 experiments with AVs. *The Communauté de communes Cœur de Brenne* (Indre) will test a shuttle circulating through three villages throughout the day.

[8] This paragraph draws on Ministère de la Transition écologique et solidaire (n.d.).

2.4 A Bibliometric Analysis of AV Policy Documents

2.4.1 Methodology

To shed a light on the differences between Korean and French AV policies, the author employs a bibliometric analysis. Specifically, the author chooses terms related to certain subjects of AV development or deployment and then compares the normalized frequencies of these terms found in the major initiatives of the two countries. One initiative is selected for each country, and the selected ones share two commonalities which improve the validity of the comparison. First, they are action-plan level comprehensive initiatives that cover major topics related to the development and deployment of AVs. Second, both of them were announced at the same time, in May 2018.

For France, the author has chosen the report, Development of Autonomous Vehicles – Strategic Orientation for Public Action, which contains the national strategy for AV development of the French government.[9] Announced in May 2018, the 96-page report presents a comprehensive framework for the policy actions of the French government for AV development (see Sect. 2.3.1). The original report in French is translated into English by the machine translation feature of Microsoft Office and then minor errors are corrected by the author. The resultant English version has 31,993 words. For Korea, section "Appendix 4. Autonomous Vehicles" of the official document of Action Plan for Innovation Growth Engine, published in May 2018, is used for the analysis.[10] Consisting of 19 pages from page 85 to page 103 of the whole document, Appendix 4 contains the comprehensive policy tasks for AV development and deployment. The original Korean document was used in the analysis given that the native language of the author is Korean. Table 2.4 presents the characteristics of the selected documents.

Given that the selected documents have different lengths, normalizing these term frequencies is necessary to compare each other. The number of words "autonomous" or "automated" in each document is used for this purpose, as these terms are the most important keywords and appear most frequently in the selected documents.[11] That is, the number of a term of interest is divided by the number of these terms to calculate normalized term frequencies. Table 2.5 shows an example of calculating the normalization of term frequency for words starting with "technolog"

[9] You can find the document at the website of the French Ministry for the Ecological and Inclusive Transition (Ministère de la Transition écologique et solidaire in French), or https://www.ecologique-solidaire.gouv.fr/vehicules-autonomes (accessed on February 28, 2020). The direct link to the PDF file of the report is https://www.ecologique-solidaire.gouv.fr/sites/default/files/90p%20VDEF.pdf (accessed on February 28, 2020).

[10] A link to the PDF file of the Action Plan is http://rnd.inha.ac.kr/schedule/download.do?id=20538 (accessed on February 28, 2020).

[11] For the Korean document, the Korean term "자율주행," which means autonomous driving, is used for this purpose.

Table 2.4 The description of the selected documents for term frequency analysis

	France	Korea
Document title	 Development of Autonomous Vehicles – Strategic Orientation for Public Action	 Action Plan for Innovation Growth Engine (Appendix 4. Autonomous Vehicle)
Document type	National strategy	National strategy
Announcement date	May 2018	May 2018
Total pages	96	19 (pp. 85-103)
Total word count	31,993 (English-translated doc.)	3,138 (Official Korean doc.)

Table 2.5 Example of normalizing term frequencies in this analysis

	France	Korea
Total word count of the document	31,993	3138
Term frequency of “autonomous” or “automated” (A)	284	103
Term frequency of “technolog*” (B)	72	91
Normalized frequency of “technolog*” in the document (C = A/B)	72/284 = 0.25	91/103 = 0.88

(e.g., technology, technologies, and technological) (technolog*, hereinafter).[12] In calculating term frequencies in the Korean document, Korean terms that have the same or almost the same meaning were used after some modification given the linguistic characteristics of Korean, taking advantage of the mother tongue of the author.

[12] For the Korean document, the Korean term “기술,” which means technology, is used.

2.4.2 Results

The first result, shown in Fig. 2.4, suggests the technology-push approach of Korea, especially focusing on the development of AV parts and communication technologies (e.g., 5G-V2X). The Korean document has the highest normalized frequency of terms technolog*, which suggests that Korean AV policy is more focused on developing AV technology than France. In addition, Korea has much higher normalized frequencies in terms "parts" or "component(s)" and in terms related to communication technology than France.[13] These results allude to what areas of technology development of AVs the Korean government aims to focus on.

The results shown in Fig. 2.5 imply the demand-pull approach of France. The French document has the highest normalized frequency of terms associated with mobility services, specifically "mobility," "transport," "service," and "use case(s)." The terms related to social acceptance, such as "social," "societal," "acceptability," and "acceptance", also have the highest frequency in the French document.

The normalized frequencies of terms related to the connectivity of AVs suggest that France and Korea have different areas of interest on this topic. The French document has the highest normalized frequency with terms associated to data management and cybersecurity, or "data*," "hacking," and "security." In contrast, the Korean document has the highest normalized frequency with terms related to communication technologies. Fig. 2.6 shows these results.

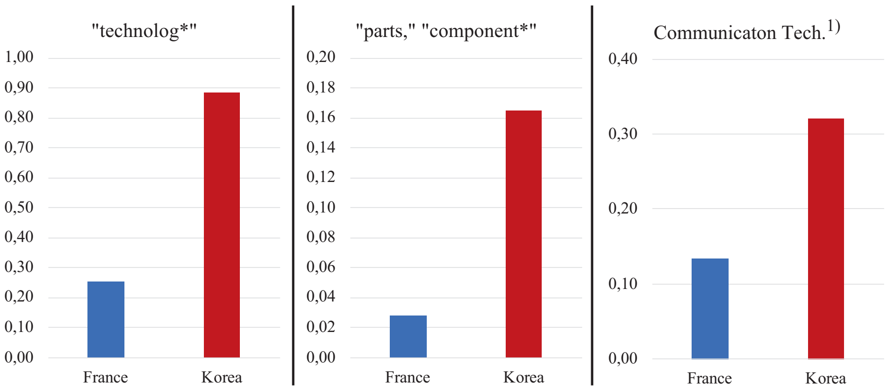


Fig. 2.4 Normalized Frequencies of Terms Related to AV Technology
1) Terms for Comm. Tech. include "V2*," "(tele)communication(s)," "5G," and "ITS-G5"

[13] The specific terms related to communication technology of AVs include "V2*," "(tele) communication(s)," "5G," and "ITS-G5." "V2*" indicates terms starting with "V2" such V2X and V2I. ITS-G5 is intelligent transport system which operates in the 5GHz range. It is an adaptation of the widely used IEEE 802.11 standard for Wi-Fi to incorporate Wireless Access in Vehicular Environments (WAVE) (Sens, 2016).

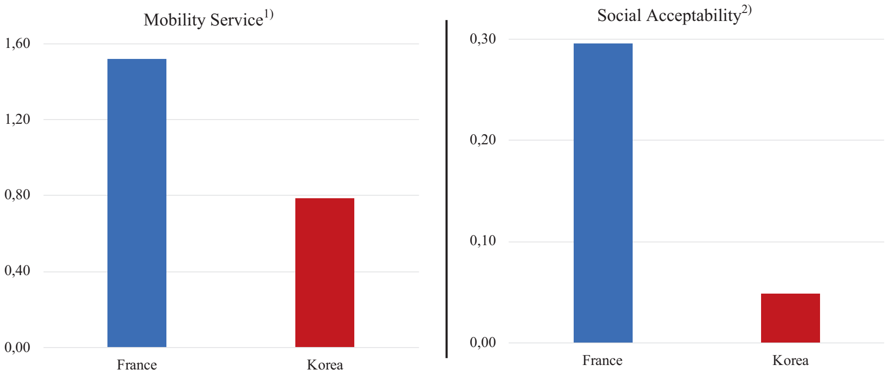


Fig. 2.5 Normalized Frequencies of Terms Related to AV Application
1) Terms include “mobility,” “transport,” “service,” “use case*”
2) Terms include “social,” “societal,” “acceptability,” “acceptance”

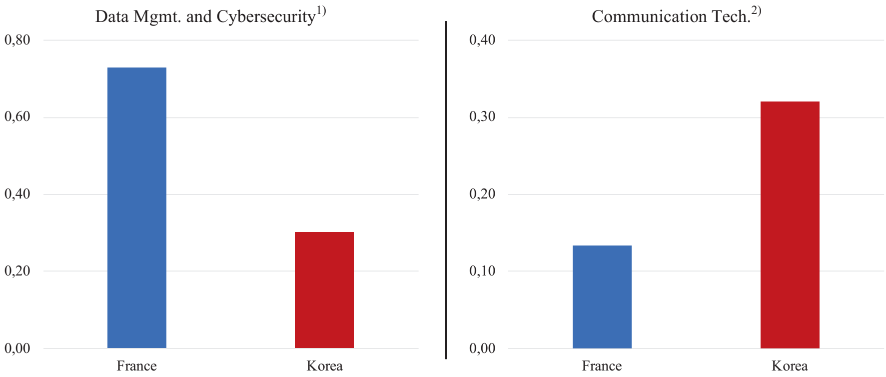


Fig. 2.6 Normalized Frequencies of Terms Related to the Connectivity of AVs*
* The figure on the right is the same as the figure on the far right one in Fig. 2.4. It is borrowed for a better visual comparison
1) Terms include “data-,” “hacking,” and “security”
2) Terms include “V2*,” “(tele)communication(s),” “5G,” and “ITS-G5”

As shown in Fig. 2.7, the French document holds the highest normalized frequency of terms related to CAV and C-ITS, specifically, “connected,” “connectivity,” and “ITS.” This result implies that France focuses on the development of connectivity-based AVs, or CAV more than Korea.

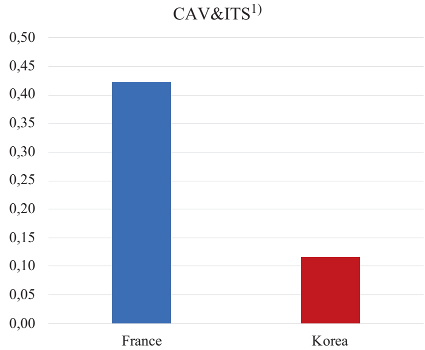


Fig. 2.7 Normalized Frequencies of Terms Related to CAV
[1)] Terms include "connected," "connectivity," and "ITS"

Table 2.6 GDP Composition, by sector of origin (2017 est.)

Country	Agriculture	Industry	Service
Korea	2.2%	39.3%	58.3%
France	1.7%	19.5%	78.8%

Note: Central Intelligence Agency (2021)

2.4.3 Discussion

The results suggest that there are two types of policy models for the commercial deployment of AVs: technology-push and demand-pull models. The technology-push model explains the AV polices of Korea, focusing on technological development and thereby mass-production of AVs. On the other hand, the demand-pull model fits the case of France, focusing on providing mobility solutions using AVs. In other words, autonomous *vehicles* are more focused in the Korean AV policies, while autonomous *mobility* is so in the French AV policies.

The two countries' different views on AVs are also reflected in the title of their first major laws on AVs. While the title of the Korean law, Act on the Promotion and Support of Commercialization of Autonomous Vehicles, includes word "commercialization," the title of the French law, Mobility Orientation Act, includes word "mobility." In the latter law, the development of AVs is addressed in the context to develop new mobility solutions or use cases of AVs (See Subsection 2.3.2.3.).

This difference in perspective may mirror the differences in the economic structure of the two countries. The Korean economy is more manufacturing sector-oriented than the French economy as presented in Table 2.6. Thus, for Korea, mass-production, sales, and exports of AVs and their parts are important in the coming era of autonomous driving. For France, on the other hand, service-oriented perspectives seem to be applied when they deal with AVs in their governmental policies given that about 80% of their economy consists of the service sector (Table 2.6).

2.5 Concluding Remarks: Comparison of Korea and France

Autonomous vehicles are expected to transform the landscape of the global automotive industry and the use of cars in our society substantially. Governments in numerous countries have been implementing national initiatives for AV development and deployment to embrace this emerging technological paradigm. Government policy tends to play a key role in socio-economic transformation especially when a new paradigm emerges. Such policy provides the *rules of the game*, which affect the practices and behaviors of consumers, producers, and intermediaries in a sector. This study comparatively analyzes national AV policies in Korea and France. Similarities contribute to shedding light on the common components of general policy for AV development and deployment, whereas differences indicate the uniqueness of the policies of the respective countries, reflecting their country-specific context of society, governance, industry, and so on.

The similarities of Korea and France found in this study include the following:

1. The AV was selected as a national strategic field in around 2013 and 2014 with a large-scale R&D investment plan (see Table 5.1).
2. One of the most important reasons for the government to develop AVs is to promote industrial competitiveness and create jobs.
3. Ministries in charge of industry, transportation, and information and communications technology and the national police agency are mainly involved in policy formulation for the development and deployment of AVs. The leading role has shifted from a ministry in charge of industry to a ministry in charge of transportation because road infrastructure and changes in transportation systems have become increasingly important topics as AV technologies have advanced toward AV deployment.

Table 2.7 summarizes flagship policies and R&D programs for the development and deployment of AVs of Korea and France.

Table 2.7 Milestones of government policy for AV development and deployment in Korea and France

Year	Korea	France
2013		New Industrial France
2014	Future Growth Engines initiative	
2015	1) Plan to Support the Commercialization of Autonomous Vehicles 2) Massive investment on AV dev. starts.	New Industrial France (Phase 2) and Industry of the Future project
2016		
2017	Innovation Growth Engines initiative	
2018	Future Car Industry Development Strategy	Development of Autonomous Vehicles
2010	Future Car Industry Development Strategy 2030	

The differences include:

1. ***The purposes of AV development***
   - France: to improve mobility for commute trips in sparsely populated areas around major cities.
   - Korea: to promote industrial growth and create new jobs.
2. ***Innovation strategy: tech-push* vs. *demand-pull***
   - France takes a demand-pull approach to make AVs socially acceptable. In other words, France focuses on developing autonomous mobility.
   - Korea, by contrast, takes a technology-push approach to make AVs technologically available. That is, Korea focuses on developing autonomous vehicles.
3. ***Focus on AV experiments***
   - France is highly active in autonomous shuttle tests with many pilot projects and trial implementation.
   - Korea has relatively few pilots and trials of autonomous mobility.
4. ***Preference for connectivity***
   - France prefers connected AVs or CAV. Thus, C-ITS development plans have integrated with AV development plans in France. This tendency is relatively not strong in the AV strategy of Korea.

These findings contribute to advancing our understanding of the different trajectories of the socio-economic transformation of Korea and France in the coming era of AVs. A bibliometric analysis in Sect. 2.2.4 provides additional basis for the abovementioned findings on the differences between the two countries. Given that autonomous mobility has a long value chain from the development of AV technology to the deployment of autonomous mobility services, the author expects the Korean and French AV policy models to converge to a mixed one as AV technology matures.

References

Antonialli, F. (2021). Autonomous shuttles for collective transport: a wordwide benchmark. *International Journal of Automotive Technology and Management, 21*(1/2), 5–28.

Central Intelligence Agency. (2021, January 28). *The world Factbook*. Retrieved January 31, 2021 from https://www.cia.gov/the-world-factbook/field/gdp-composition-by-sector-of-origin/

des Grottes, G. M. (2020, January 6). *LOM et véhicules autonomes : Modifications en vue du Code des transports et de la responsabilité civile* [LOM and autonomous vehicles: Amendments to the Transport Code and civil liability]. Wolters Kluwer. Retrieved February 23, 2020 from https://www.actualitesdudroit.fr/browse/tech-droit/objets-connectes/25290/lom-et-vehicules-autonomes-modifications-en-vue-du-code-des-transports-et-de-la-responsabilite-civile

Development of autonomous *vehicles – Strategic orientation for public action (Summary document).* (2018, May). http://www.ecologique-solidaire.gouv.fr/sites/default/files/18029_D%C3%A9veloppement-VA_8p_EN_Pour%20BAT-3.pdf

Gelpi, B., & Guillemare-Grilo, M.-A. (2019, July 12). *European Union: The PACTE Act: Changes impacting French financial law*. Mondaq. https://www.mondaq.com/Finance-and-Banking/825254/The-Pacte-Act-Changes-Impacting-French-Financial-Law

Giono, S. (2019, July 10). *European Union: French legal and regulatory update - May 2019.* Mondaq. Retrieved February 23, 2020 from https://www.mondaq.com/Article/823680/French-Legal-And-Regulatory-Update-May-2019

Gouvernement de la République française. (2016, May 23). *Nouvelle France Industrielle : Construire l'industrie française du futur* [New Industrial France: Building France's industrial future]. https://www.entreprises.gouv.fr/files/files/directions_services/politique-et-enjeux/nouvelle-france-industrielle/industrie-du-futur-dp-2016-05-23.pdf

Hölscher, L., & Jensterle, M. (2018, December 5). *The Energy Transition for Green Growth Act in France.* Adephi. https://www.euki.de/wp-content/uploads/2018/12/Fact-Sheet-Energy-Transition-Act-FR.pdf

Ki, J. (2020). *A comparative analysis of autonomous vehicle policies among Korea, Japan, and France* (FFJ Discussion Paper #20-02). Fondation France-Japon de l'EHESS. https://hal.archives-ouvertes.fr/hal-02562482

KPMG International Cooperative. (2019, February). 2019 Autonomous Vehicles Readiness Index: Assessing countries' preparedness for autonomous vehicles. https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/02/2019-autonomous-vehicles-readiness-index.pdf.

La loi mobilités [Mobility law]. (2020, January 27). Ministère de la Transition écologique et solidaire. Retrieved February 23, 2020 from https://www.ecologique-solidaire.gouv.fr/loi-mobilites-0

La nouvelle France industrielle: Présentation des feuilles de route des 34 plans de la nouvelle France industrielle [New Industrial France: Presentation of the roadmaps for the 34 plans of the New Industrial France]. (2014). https://www.economie.gouv.fr/files/files/PDF/nouvelle-france-industrielle-sept-2014.pdf

La nouvelle France industrielle [New Industrial France]. (2017, May 15). The French Government. Retrieved February 22, 2020 from https://www.gouvernement.fr/action/la-nouvelle-france-industrielle

Les véhicules autonomes [Autonomous vehicles]. (2020, January 10). Ministère de la Transition écologique et solidaire. Retrieved February 26, 2020 from https://www.ecologique-solidaire.gouv.fr/vehicules-autonomes

Ministère de la Transition écologique et solidaire. (n.d.). *Loi mobilités : Accélerer la révolution des nouvelles mobilités* [Mobility law: Accelerating the new mobility revolution] [Brochure]. http://www.ecologique-solidaire.gouv.fr/sites/default/files/V2-Acc%C3%A9lerer%20la%20r%C3%A9volution%20des%20nouvelles%20mobilit%C3%A9s.pdf

Ministry of Land, Infrastructure and Transport. (2018, February 2). *Ca-yul-cwu-hayng sang-yong-hwa-lul wi-han su-ma-thu-kyo-thong-si-su-theym kwu-chwuk-pang-an* [Plan for the establishment of smart traffic system for the commercialization of autonomous driving] [PowerPoint slides]. Ministry of Trade, Industry and Energy. http://www.motie.go.kr/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=160144&file_seq_n=6

Ministry of Land, Infrastructure and Transport. (2020, January 9). Ceng-pwu-nun pwu-pwun-ca-yul-cwu-hayng-cha sa-ko-ey tay-pi-han po-hem-cey-to-lul kyey-hoyk-ey tta-la cha-cil-eps-i cwun-pi-ha-ko iss-sup-ni-ta. [The government is preparing an insurance system against partial autonomous vehicle accidents according to the plan.] [Press release]. http://www.molit.go.kr/srocm/USR/N0201/m_13551/dtl.jsp?id=95083392

Motor Vehicle Management Act 1995 & rev. (2018, December 31 (Kr)). http://www.law.go.kr/LSW//lsInfoP.do?lsiSeq=206304&chrClsCd=010203&urlMode=engLsInfoR&viewCls=engLsInfoR#0000

Office for Government Policy Coordination. (2018, November 7). *Ca-yul-cwu-hayng-cha mi-lay, mi-li nay-ta-po-ko sen-cey-cek-u-lo kyu-cey-hyek-pha: Ca-yul-cwu-hayng-cha pwun-ya sen-cey-cek kyu-cey-hyek-pha lo-tu-mayp pal-phyo* [Autonomous vehicle future, looking ahead and proactively reforming regulations: Announcement of a roadmap for preemptive regulatory reform in the field of autonomous vehicles] [Press release]. Prime Minister's Secretariat. http://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?id=95081533

Organisation for Economic Co-operation and Development. (n.d.). *OECD Science, Technology and Industry Outlook Policy questionnaire 2014* (STIO_2014) [Data set]. https://qdd.oecd.org/DATA/STIPSurvey

PACTE, the Action Plan for Business Growth and Transformation. (n.d.). The French Government. Retrieved February 23, 2020 from https://www.gouvernement.fr/en/pacte-the-action-plan-for-business-growth-and-transformation

Park, W. (2020, January 3). Cwung pa-i-twu, say-hay pey-i-cing-se yu-in ca-yul-cwu-hayng thayk-si si-pem wun-hayng... han-kwuk-un? [China's Baidu to pilot a manned self-driving taxi in Beijing in the New Year ... how about Korea?]. *Chosun Biz.* https://biz.chosun.com/site/data/html_dir/2020/01/02/2020010203043.html

Présentation du rapport "Développement des véhicules autonomes : Orientations stratégiques pour l'action publique" [Presentation of the report "Development of autonomous vehicles: Strategic directions for public action"]. (2018, May 14). Ministère de la Transition écologique et solidaire. Retrieved February 22, 2020 from https://www.ecologique-solidaire.gouv.fr/presentation-du-rapport-developpement-des-vehicules-autonomes-orientations-strategiques-laction

Road Traffic Act 1961 & rev. (2018, March 27 (Kr)). http://www.law.go.kr/LSW//lsInfoP.do?lsiSeq=202947&chrClsCd=010203&urlMode=engLsInfoR&viewCls=engLsInfoR#0000

Ryu, J. (2020, January 28). Tay-kwu si-min-to sey-cong si-min-to pom-pwu-the ca-yul-cwu-hayng sye-thul thap-ni-ta [Daegu citizens and Sejong citizens also take autonomous shuttles from spring]. *The Chosun Ilbo.* https://biz.chosun.com/site/data/html_dir/2020/01/28/2020012800074.html

Sens, T. (2016, June 16). Self driving cars: G5 or 5G?. *Nokia.* https://www.nokia.com/blog/self-driving-cars-g5-or-5g/

Chapter 3
How to Assess Regulation Openness for Autonomous Driving in Public Transport? The ROAD Index

Sylvie Mira-Bonnardel and Elizabeth Couzineau

Abstract This chapter identifies and maps regulatory and legislative requirements and procedures for the deployment of autonomous public transport. After providing a general overview on the international and European organizations involved in regulatory statements and the branches of law framing regulation for public transport, we propose a tool to evaluate the level of regulation framework openness to robomobility, the ROAD index (the Regulation Openness for Autonomous Driving index). Taking into account regulations and policy making processes, we distinguished a set of four variables to measure the level of national or local readiness for the implementation of autonomous collective vehicles on open roads. ROAD index helps to evaluate regulation as facilitator or barrier to robomobility and to understand in which way decision makers can leverage on regulation to make it build a favorable framework for mobility innovation.

Keywords Robomobility · Autonomous public transport · Regulation · Regulatory assessment tool

---

S. Mira-Bonnardel (✉)
École Centrale Lyon, Écully, France
e-mail: sylvie.mira-bonnardel@ec-lyon.fr

E. Couzineau
PPA Business School, Paris, France
e-mail: ecouzineau@ppa.fr

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_3

3.1 Introduction

Since the first project aimed at smart mobility and services launched in 2010 on a European scale – the CATS project (City Alternative Transport System), a three-year project (2010–2012) – European and national governments have been considering urban transport disruption, targeting more specifically collective transport regarding the potential for robotization, i.e. the integration of buses operating without a driver, automated or autonomous buses.

From there, national and regional regulators have authorized many experiments of so-called robomobility in order to study the feasibility of setting up a transport network integrating autonomous buses. From a worldwide benchmark conducted in 2019, Antonialli (2021) listed no less than 176 experimentations worldwide, of which 104 were already finished, 57 were currently running and 15 were yet to start. These 176 projects unfold in 142 cities spread over 32 countries around the world, enabled by 20 different autonomous vehicles manufacturers. As stated by Antonialli in Chap. 1, the stake is to offer city travelers autonomous buses as part of their public transport network. This implies that regulation should allow driverless buses to operate on mixed roads alongside trucks, cars, bicycles, pedestrians, etc. As of today, all experimentations have been introduced with low legal requirements, the testing of automated vehicles being permitted as long as the test organization got the permit approved, most often under the condition that a driver (or on-site operator) is present in the vehicle and can, at any time, disable automated driving and take control of the vehicle (see Chap. 9 for empirical details from the EU project AVENUE).

As detailed in Chap. 2, in France, the French National Assembly passed the Mobility Orientation Law in December 2019 *(*L*oi d'orientation des mobilités, LOM)* and the ministry of transport declared that a shared use of autonomous vehicles of various sizes, integrated into local mobility network, seems more promising than an individual use claiming that robomobility for goods logistics should further enrich the use cases with new players.

However, worldwide, transport operators and manufacturers are still waiting for the establishment of their own national framework for the validation of automated public transport systems and, at the European and international levels (UNECE), a technical regulation and approval framework specific to the autonomous vehicle.

Indeed, regulation appears clearly double-sided since regulatory compliance can either restrict or facilitate transition towards a new urban mobility. Regulatory authorities may either create obstacles for the release of autonomous vehicles or shape a uniform set of laws that promotes robomobility as the best solution for the renewal of public transport (Brodsky, 2016).

Regulation can be interpreted broadly as a social mechanism of control or, more specifically, as a set of authoritative rules, accompanied by some administrative agency for monitoring and enforcing compliance (Jordana & Levi-Faur, 2004).

Autonomous vehicles indeed raise new challenges to which the law must now bring adapted responses in view of new risks and liabilities. New risks concern, on the one hand, General Data Protection Regulation and cybersecurity, and, on the other hand, driving task delegation from human to machine.

Regulation for robomobility represents a very complex issue lying at the crossroads of three main legal fields: civil, criminal and administrative laws. The question of liability is the cornerstone of any regulatory modification.

For a decade now, regulation on the deployment of autonomous vehicles for public transport has undergone profound changes and regulators are still working on it. Therefore, the objective to give an image of current regulation in 2020 would be useless because this picture would quickly become obsolete.

More important than the knowledge of the complete regulatory spectrum, which is rapidly changing, the challenge for robomobility stakeholders is to anticipate and balance the governance of risks associated with the regulation process and evaluate the impact on the deployment of the new technology.

Therefore, the chapter aims to provide an overview of the regulatory framework and proposes a methodology to assess, on a national or a regional level, to which extent regulation may be considered as facilitator or barrier for the deployment of robomobility. The methodology is based on the assessment of a specific index: the ROAD index, Regulation Openness for Autonomous Driving index.

The ROAD index provides a metric to assess the impact of regulation on the deployment of mobility innovations, such as robomobility. The ROAD Index has been designed by mixing research articles, documentary reviews and experts' interviews.

We think that the understanding of the regulation design process and of the implied organizations undoubtedly helps to anticipate legislative evolutions.

The chapter is organized as following. After the introduction in section 3.1, sections 3.2 presents how international and European organizations have tackled the regulatory issue for robomobility. Section 3.3 characterizes the legal framework in which the regulatory design process is embedded and the specific criteria that influence regulatory design for local mobility policy. We present the methodology to assess whether a regulatory design context may play as facilitator or barrier for robomobility based on 4 variables scoring for the ROAD index and apply this index to four European cities.

3.2 The International and European Regulatory Frameworks for Robomobility

Current regulation concerning road and driving are clearly in conflict with autonomous vehicles development (Beland, 2005; Mordue, Yeung, & Wu, 2020). Robomobility induces a transfer of responsibility from humans to robots which is the very reason for this conflict because existing international laws are based on the concept of responsibility that is very difficult to adapt to robots (Li, Sui, Xiao, & Chahine, 2019).

Regulatory and legal issues are one of the main concerns for the introduction of highly automated driving systems. The responsibility and liability of all stakeholders need to be clear; manufacturers, service providers and government and transport operators need to be aware of their rights and obligations related to the use of automated vehicles.

In that purpose, legislators are discussing the evolution of the Vienna Convention on Road Traffic of 1968, as well as the Geneva Convention on Road Traffic of 1949, which are both fundamental elements governing the obligations of the driver at the international level. The objective is to design a common regulatory framework that facilitates robomobility deployment. Since traffic does not stop with national frontiers and interoperability is crucial, discussions are conducted at two main levels: the international level and the European level.

3.2.1 The International Framework: Toward a Worldwide Harmonization

International work on regulation is still making some progress mainly within the United Nations Economic Commission for Europe (UNECE), one of five United Nations regional commissions administered by the Economic and Social Council (ECOSOC). UNECE was established in 1947 to encourage economic integration and cooperation among its member countries. Among various sectoral divisions, the UNECE Sustainable Transport Division works to facilitate the international movement of people and goods by inland transport modes. It aims to improve competitiveness, safety, energy efficiency and security in the transport sector.

The Inland Transport Committee (ITC) is the highest policy-making body of the UNECE in the field of transport. Together with its subsidiary bodies, the ITC has provided a pan-European inter-governmental forum, where UNECE member countries come together to discuss tools for economic cooperation, to negotiate and to adopt international legal instruments on inland transport.

UNECE is at the center of the legal and regulatory work needed to realize the vision of new sustainable mobility and support the mass introduction of autonomous vehicles on the roads. It started dedicated works on this issue back in 2014. Since 2014, the UNECE's Sustainable Transport Division has provided a multilateral platform for the negotiation of international legal instruments.

In this framework, two milestones were reached in 2016: firstly, the 1968 Vienna Convention on Road traffic was amended to open the door to automated vehicles in traffic; secondly, the 10 km/h limitation for autonomous systems was removed from UN Regulation No. 79.

The World Forum for Harmonization of Vehicle Regulations, hosted by UNECE, is the intergovernmental platform that defines the technical requirements applied by the automotive sector worldwide. Today, automation is the priority of the Forum's work. (UNECE, 2019a). Within UNECE, efforts are on to enable traffic of automated vehicles at higher levels (UNECE, 2019b). So far, however, the organization still requires a driver in each vehicle on the road.

One of the most important critical ambitions of the World Forum for Harmonization of Vehicle Regulations is to consolidate the international harmonization of vehicle regulations (WP.29). At the forum of February 2020 session (178th session), the group proposed a framework to provide guidance for harmonization by identifying key principles for the safety and security of autonomous vehicles of levels 3 and higher[1]. This document has been prepared by the representatives of China, the European Union, Japan and the United States and has been endorsed by the Inland Transport Committee of UNECE.

Issues currently covered by the framework are threefold:

1. Safety, concerning as well people inside the vehicle as people around, and the safe integration of autonomous vehicles in road traffic
2. Connectivity, cyber security and data protection regarding personal data protection as well
3. Liability and responsibility in case of injuries

3.2.1.1 Safety and Integration in Road Traffic

According to the framework, the level of safety to be ensured by autonomous vehicles implies that an autonomous vehicle shall not cause any non-tolerable risk, meaning that automated/autonomous vehicle systems, under their full self-driving mode, shall not cause any traffic accidents resulting in injury or death that are reasonably foreseeable and preventable. Based on this principle, this framework sets out a series of vehicle safety topics to be taken into account to ensure safety:

– **System safety**: When in the self-driving mode, the vehicle should be free of unreasonable safety risks to the driver and other road users (pedestrians, bicycles, cars, etc.) and ensure compliance with road traffic regulations.
– **Failsafe response**: The system should be able to detect its failures or when the conditions for autonomous driving are not met anymore.
– **Human machine interface**: The system should include driver engagement monitoring and request the driver to hand over the driving tasks in any case the driver needs to regain a proper control of the vehicle. In case of a driverless vehicle, the system should allow interaction with an external supervisor.

3.2.1.2 The Evolution of Regulation 79 on Safety

"Over the past decades, developments in vehicle safety have contributed significantly to the overall reduction in the number of road fatalities and severe injuries. However, 25 300 people died in 2017 on Union roads, a figure that has stagnated in the last four years. Moreover, 135 000 people are seriously injured in collisions

[1]According to the document Automated Driving definitions referenced in WP.29 ECE/TRANS/WP.29/1140, adopted in March 2018

every year. The Union shall do its utmost to reduce these figures drastically aiming at the Vision Zero goal of "no fatalities".

In addition to the safety measures to protect vehicle occupants, the implementation of specific measures to prevent fatalities and injuries of vulnerable road users, such as cyclists and pedestrians, is needed to protect users outside of the vehicle. Without new initiatives on general road safety, the safety effects of the current approach will no longer be able to off-set the effects of increasing traffic volumes. Therefore, the safety performance of vehicles needs to be further improved as part of an integrated road safety approach and in order to protect vulnerable road users better." (Regulation (EU) 2019/2144).

Automated vehicles may be able to make a huge contribution in reducing road fatalities since more than 90% of road accidents are estimated to result from some level of human error. As computer-driven vehicles will gradually be taking over tasks of a driver, harmonized rules and technical requirements for automated vehicle systems should be adopted at the UNO level and promoted at international level in the framework WP9 of the United Nations Economic Commission for Europe.

For example, advanced emergency braking or emergency lane-keeping systems might not be fully operational in some cases, in particular due to shortcomings in the road infrastructure. In those cases, the systems should deactivate themselves and give information about the deactivation to the driver. If they do not deactivate automatically, it should be possible to switch them off manually. Such deactivation should be temporary and last for a period when the system is not fully operational only. Drivers may also need to override advanced emergency braking systems or emergency lane keeping systems, where the functioning of the system could lead to greater risk or harm. This ensures that the vehicles are at all times under the driver's control. Nevertheless, the system could also recognize instances where the driver is incapacitated and therefore intervention by the system is needed in order to prevent the worsening of an accident.

Safe integration of autonomous vehicles in road traffic is allowed by the use of two tools: Object Event Detection and Response (OEDR), Validation for System Safety (VSS).

– **OEDR** aims to detect and respond to object/events that may be reasonably expected in the cases portfolio.
– **VSS** obliges vehicle manufacturers to demonstrate a robust design and validation process based on a systems-engineering approach with the goal of designing automated driving systems free of unreasonable safety risks and ensuring compliance with road traffic regulations.

3.2.1.3 Cybersecurity and Personal Data Protection

Cybersecurity issues go along with anonymity and personal data protection hardening as well as system's hacking. Autonomous vehicles should be protected against cyberattacks in accordance with established best practices for cyber vehicle physical systems. Vehicle manufacturers should ensure that system updates occur as needed in a safe and secure way and provide for after-market repairs and modifications as needed.

The French Data Protection Authority (CNIL[2]) worked to encourage innovation ecosystems while ensuring the protection of car users' personal data and proposed in 2018 a compliance plan linked with the European General Data Protection Regulation for connected vehicles. The CNIL examined three scenarios.

- Scenario #1 – IN => IN: collected data stay in the vehicle and are treated by the system for appropriate responses.
- Scenario #2 – IN => OUT: collected data are transmitted to a third part and are saved and treated outside the vehicle.
- Scenario #3 – IN => OUT => IN: data is collected in the vehicle and transmitted externally to trigger an automatic action in the vehicle.

Data concern the vehicle user (name, civil status, e-mail address, biometric data, etc.), the vehicle (serial number, plate number, etc.), the geolocation, the state of the vehicle and its parts, the use of the vehicle by the occupants. Processing of such data, shall only involve information that is relevant, adequate and not excessive with regard to the purpose of the file, i.e. its objective.

In that regard, the General Data Protection Regulation refers to the principle of "data minimization" (article 6-3 of the French Data Protection Act, and article 5-1 of the EU General Data Protection Regulation[3]). The objective is to regulate remote access to car data needed for the deployment of mobility services. Meanwhile, service providers have to make people aware why they are asked to give their data.

3.2.1.4 Liability Attribution

Liability issues are linked with data collection and protection. It is treated with the event data recorder (EDR) and the Data Storage System for Automated Driving vehicles (DSSAD). These tools are built to establish the cause and the responsibility in case of a crash.

- **EDR** collects and records the necessary data to understand what or who was controlling the driving in case of a crash.
- **DSSAD** collects and records the necessary data to reconstruct the last moment before a crash and identify the status of the driving system.

According to Guilbot (2017), the law seems sufficient to address conflictual situations involving an autonomous vehicle, but measures need to be implemented to identify causality and liability. Data collection is part of that, but practices must comply with all legislation, particularly European legislation, regarding the personal data protection and the privacy of users.

[2] Commission nationale de l'informatique et des libertés

[3] Regulation (EU) 2016/679, General Data Protection Regulation, OJ L 127, 23.5.2018

Yet, many questions related to liability attributing remain open. Indeed, in the absence of specific legislation, vehicle owners, i.e. transport operators, will remain liable in the first instance for incidents caused by their autonomous vehicles. However, if an accident occurs in an autonomous bus as a result of an error or shortcoming in the system as opposed to resulting from carelessness on the part of the owner, in some cases it might be considered unfair to attribute the incidents to the vehicle owner.

A number of complicated liability questions arise in relation to incidents involving autonomous vehicles. For example, what if the vehicle had made a choice that a driver would never have chosen: should the transport operator be responsible? Who should be responsible for incidents caused by defects in the software? The car manufacturer? The manufacturer of the software that failed to prevent the accident? Who should be held liable in the case of a cyber-attack on vehicles? Should the software manufacturer be strictly liable for defective software security that allowed third parties to hack into the car? Or should the transport operator be liable if, for example, they had failed to download software security updates? Should network providers be held liable if accidents are a result of a defect in connectivity causing the incident? (Fagnant & Kockelman, 2015).

With the increase in event data recorders (also known as insurance black boxes) in vehicles, it should become easier to determine exactly the cause of an accident (subject to privacy implications). However, fault for the accident will still need to be attributed. Additionally, there is the question of who should insure the vehicle. Should all relevant parties contribute to the insurance? Will car owners still be required to have third party liability insurance? Will car manufacturers be legally required to have product liability insurance? Will accidents in autonomous vehicles fall under the product liability regulations preventing any limitation on the bringing of claims against the manufacturer? Or if a network provider is liable, will telecoms liability limitations apply?

In the United Kingdom, 11 major insurers, including Aviva and Direct Line, have been working together to provide a framework for insuring autonomous vehicles (House of Lords, 2016). One option being considered is expanding compulsory insurance to cover product liability; another one is the manufacturer takes all responsibility for its products.

3.2.2 The European Framework: Slow but Determined Progress

On the European level, a road map has started in 2016 with the creation of Europe's first Automotive-Telecom Alliance. The Alliance includes six leading sectoral associations, as well as 37 companies, including telecom operators, vendors, vehicle manufacturers and suppliers for both cars and trucks. The main goal of this Alliance is to promote the wider deployment of connected and automated driving in Europe.

The first concrete step is the advancement of a "Pre-Deployment Project" aimed at testing major use-case categories. These tests aimed to identify and address both technological and regulatory issues, interoperability issues as well as infrastructure investment to address connectivity needs, safety and security (ACEA, 2016).

In Europe the regulatory framework is defined by European Union directives, regulations and standards. However, European countries may promote their own specific regulatory framework using the United Nations Economic Commission of Europe (UNECE) regulation requirements as a base.

All European Parliament legislative initiative reports (INI) must automatically be accompanied by a detailed European added value assessment (EAVA). The purpose of the European added value assessment is to support a legislative initiative of the European Parliament by providing a scientifically based evaluation and assessment of the potential added value of taking legislative action at EU level. In 2018, the EAVA suggested that it was necessary to revise the current legislative EU framework for liability rules and insurance for connected and autonomous vehicles.

Not only would revision ensure legal coherence and better safeguarding of consumers rights but it would also be likely to generate economic added value. The report argues that accelerating the adoption curve of driverless or autonomous vehicles by five years has the economic potential to generate European added value worth approximately €148 billion (Evas, 2018).

In 2017, 29 European countries, Members of the European Union and of the European Economic Area, signed a Letter of Intent to intensify cooperation on testing of automated road transport in cross border test sites. The EU objective is that all member countries profit from artificial intelligence for mobility, AI being considered as a common good.

In 2018, the European Commission presented a document titled: "On the Road to Automated Mobility: An EU strategy for Mobility of the Future" (EU, 2018). That document proposes "a comprehensive EU approach towards connected and automated mobility, setting out a clear, forward looking and ambitious European agenda" in order to "ensure that EU legal and policy frameworks are ready to support the deployment of safe connected and automated mobility" (EU, 2018). In addition, the Commission published guidelines for EU approval of automated vehicles (EU, 2019). Hence, the EU strives to harmonize legislation on the automation of vehicles among its member states. To clarify discussion, European Union law distinguished two kinds of autonomous vehicles (Table 3.1).

Table 3.1 European classification for autonomous vehicles

Automated vehicle	Fully automated vehicle
A motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required.	A motor vehicle that has been designed and constructed to move autonomously without any driver supervision.

Table 3.2 European Compliance Requirements

Technical specifications for autonomous vehicles	Systems to replace the driver's control of the vehicle, including signaling, steering, accelerating and braking; Systems to provide the vehicle with real-time information on the state of the vehicle and the surrounding area; Event data recorders for automated vehicles; Harmonized format for the exchange of data between vehicles; Systems to provide safety information to other road users.

For the European law, automated vehicles and fully automated vehicles shall comply with the technical specifications set out in the implementing acts that relate to five main items (Table 3.2).

By 31 January of each year, the Commission shall submit to the European Parliament and to the Council a report on the activities of the UNECE's World Forum for Harmonization of Vehicle Regulations (WP.29) as regards the progress made on the previous year, in the implementation of vehicle safety standards and as regards the position of the Union related to these matters.

Besides international and European levels, national governments are also taking over to transform regulatory requirements. For example, on 5 September 2019, a new law on mobility was presented by the French government to the French parliament whose members discussed its application during fall. In order to improve the mobility for all residents, the French government has decided to deeply transform the mobility system, starting with the rail system in 2018, it targets, in 2019, daily and short motilities, with a clear openness to innovation in product and services. 13.4 billion euros will be invested to implement new motilities and help everyone to commute (Urban Mobility Company, 2020).

The French government wants to involve all stakeholders in the mobility plan, mainly companies and territorial authorities, to provide alternative solutions to personal vehicles by means of autonomous vehicles, shared mobility, on-demand mobility, intermodal mobility services platform, all supported by digital technologies. The law also aims at improving mobility for disabled people like free mobility-specific services for assistants; autonomous vehicles are expected to expand from 2020 onwards for urban mobility. A legal framework for free-floating is about to help transactions between delivery platforms, taxis and drivers.

3.2.3 The Regulatory Design Process for Robomobility: A Threefold Legal Framework

The regulatory framework for robomobility is shaped by the convergence of three main branches of law: the administrative law, the civil law and the criminal law.

3.2.3.1 The Administrative Law

The administrative law includes road traffic law in general and covers, among others issues, such as certification and licensing, technical controls, road traffic rules, etc. It deals with stating technical norms as well. The most important legal challenges related to autonomous driving in the area of administrative law are in the field of user requirements as well as use requirements (Fagnant & Kockelman, 2015).

3.2.3.2 The Civil Law

Civil law covers legal, the most significant being linked with civil liability: damage and/or injury (hence insurance issues) and product liability (defective product). Two different conceptual approaches could contribute to understanding liability.

The first approach is based on a compulsory motor third party liability (MPTL) insurance under the regime of strict liability by mandating autonomous vehicle manufacturers to contribute a portion of the insurance for each individual vehicle. However, manufacturers would be exempted from product liability for injury and damage that is covered under the compulsory MPTL insurance regime and that was caused by a product defect affecting autonomous vehicle functionality, unless the defect is the result of gross negligence. This approach is rather theoretical than pragmatic due to possible administration difficulties.

The second approach suggests product liability to be further sharpened, the requirement of a product defect should be omitted. Instead, the manufacturer should be held liable for injury and damage caused by the way goods acted (i.e. the way of their actions and behavior; their effect; and the failure of the goods to act or to behave in a particular way, or to have a particular effect). The main argument for this approach is the following: while autonomous vehicles will be much safer than conventional cars, the technology in the product is so complex that there is an uncontrollable residual risk of malfunctioning even when the product is free from defects. Hence, the legislation should introduce an irrefutable presumption of a defect in a highly or fully automated vehicle that causes an accident, unless the manufacturer can prove that the autonomous vehicle functionality was not the cause of the accident. The MTPL regime would, in this alternative, remain identical to the first approach, except that manufacturers would not be incorporated into the MTPL system (Ilkova & Ilka, 2017).

3.2.3.3 The Criminal Law

Autonomous driving-inspired legal challenges in the area of criminal law include especially the issue of criminal responsibility as well as protection against cyber-crime and hackers. In general, research in this area is dealing with the following questions.

- What crimes may be committed with autonomous vehicles?
- Who should be held responsible in case, when using an autonomous vehicle, a crime is committed: the owner, the person who is sitting in the driver's seat (if there is any kind of it), the vehicle manufacturer, the software designer or another entity?
- Will the responsible subject change according to the circumstances and if so, how?
- How should the law react if the criminally responsible subject is a legal entity?

As for the criminal responsibility for harm caused by an autonomous vehicle, according to most European states' criminal codes, the driver (or vehicle owner) may be charged with negligence even if the autonomous vehicle was in control (in autonomous mode). In case of no proved negligence, the criminally responsible entity is the manufacturer. Since, in most cases, a vehicle manufacturer is a legal entity, it is highly important to consider the issue of corporate criminal responsibility. The European Union countries do not have an identical legislation in this area. Personal guilt is the basement of criminal codes in most countries; these codes would definitely need an amendment (Ilkova & Ilka, 2017).

In Part 2, we have provided an overview of the regulatory framework governing the deployment of autonomous vehicles and the main challenges regulators have to face to pave the way for robomobility for public transport.

The regulatory framework has been constantly evolving for a decade and heavy changes are still to come. Currently, public transport operators' (PTO) concern is to understand and anticipate forthcoming regulatory requirements. PTOs have to decide their investments upstream, years before regulation approval, and they need to consider whether regulation will help or restrict autonomous buses.

To cope with the uncertainty, eavesdropping on UE parliament's meetings may be an option, which limits anticipation. To be proactive, PTOs have to understand the regulatory design process, at national as well as local levels.

Therefore, we propose a new methodology to assess whether the regulatory framework may facilitate or hinder the deployment of autonomous vehicles for public transport. This methodology is based on the ROAD index; it is presented and applied to four cities in the next section.

3.3 Regulation Assessment: The Regulatory Openness for Autonomous Driving Index (ROAD Index)

Apart from implementing a permanent scanning on all regulatory modifications, decision makers need to anticipate whether under the current regulation they'll have to comply with may facilitate or hinder autonomous driving for public transport. Therefore, they have to understand the framework of regulatory design as well as their political and organizational context.

Jordana and Levi-Faur (2004) bring forward four factors that need to be addressed in a regulatory process. Depending on how flexible these factors are, a regulation can be more or less open to innovation and new technological changes. The first factor is flexibility: a high adjustment flexibility allows a redesign of regulations in light of new technical innovations or new scientific findings. The second factor is issue definition: an effective regulatory design needs relevant information identifying the problems that are to be regulated distancing from industry interests for considering interest of the public at large. The third factor is adaption to the context whether at national, regional or local level. The fourth factor is the predictability of regulatory outcomes, which need relevant indicators (Jordana & Levi-Faur, 2004).

Experiments and innovations for public transport are authorized by certification bodies and local decision-making bodies, like municipalities. But the integration in public transport, meaning common transit pass for example, requires various authorizations.

Therefore, a city's openness to public transport innovation, like the introduction of autonomous vehicles, depends on the city/country decision process and the existence or not of an active governance organization. This organization is generally composed of city politicians and representatives of the PTO. For instance, two cities, Geneva and Lyon have had, for many years, this governance organization. Copenhagen has this organization only since the beginning of 2019 (see Chap. 2 for further details).

Since standardization from the European level will remain limited, the evaluation of regulatory as barriers or facilitators depends more on the local decision process of a specific area like a city. Therefore, we propose a methodology to assess the local regulatory system through the scoring of the Regulatory Openness for Autonomous Driving (ROAD Index).

The prospective issues of the autonomous vehicle and, more precisely, autonomous buses, have to be apprehended on several dimensions; the first being the distinction between the autonomous car and the autonomous bus, insofar as the uses are different, the related regulations are also different: to date, the cars are not intended to be considered as public transport, in the sense of a full integration into an urban transport network. This distinction could obviously evolve, for example, with robots-taxis or on-demand collective transport.

Apart from the technical progress expected and the R&D efforts of the manufacturers, the conditions of development for autonomous buses are twofold: regulation and political will.

The regulatory issue of the vehicle itself falls under the European and national level for approval, levels of security, global traffic permits on roads (open road, private site, etc.) and more generally its use of infrastructure..

The political will to implement an automated public transport service relies on three motivations: (1) revive, support and strengthen industrial policy, in particular the automotive industry and its derivatives; (2) revive, support and strengthen the country's competitiveness (in economic terms, but also in terms of attractiveness); (3) gain a pioneer position or become a model to copy.

At the local level, these three dimensions are combined with the objective of boosting the territory's attractiveness, whether in terms of inhabitants, business location or investors. The development of competitiveness clusters is an illustration of these motivations.

The manifestation of political will involves the definition and implementation of political and financial tools and the adaptation of the regulatory apparatus. Again, there are distinctions to be made between the national and local levels.

At the national level, some states are developing programs to fund experimental or demonstration projects with autonomous vehicles. The purpose of these projects is to be able to change the regulatory frameworks and to identify the obstacles and levers on which the state could intervene to favor the development of the sector (within an industrial policy framework) or to favor new uses for the development of a carbon-free mobility, for example.

At the local level, transport and mobility policies allow tests in situ of autonomous buses, local authorizations of experimentation granted but conditioned to their conformity with the national regulations.

The main issue surrounding the regulatory and political aspects of the deployment of autonomous buses concerns the confrontation and convergence of political will at national and local levels and the distance between the executive and the legislative bodies (short circuit vs. long circuit and intermediaries), which also refers to the complexity of the political systems of the various states composing Europe.

This issue can be addressed by analyzing different variables contributing to policy making in the mobility ecosystem. Scoring these variables helps to understand the impact of regulation on mobility innovation. These variables are described in the next sub-section.

3.3.1 Variables Scoring for the Index

We identified four variables that help to diagnose whether regulation can be considered as a facilitator or as a barrier to the development of autonomous mobility in a specific area, such as a city in a specific country. These variables are:

1. National Industrial policy
2. Local territories autonomy
3. National sustainable development policy and declination
4. Governance and integration at local level

3.3.1.1 Variable 1 – National Industrial Policy Strength

Industrial policy becomes a competitiveness-oriented policy defined by Michael Porter (1990) as a set of state interventions encompassing both business-environment interventions that are essential for promoting the development of the fabric of firms and improved competitiveness and direct interventions with targeted enterprises in small but well-identified sectors, to help overcome bottlenecks and market imperfections.

Although the market is considered the best system of economic coordination by liberal economists, analyses of the process of industrial transformation show that markets alone are not enough to start and sustain the process of industrial transformation. Industrial policy plays a facilitating role in industrial modernization and economic diversification in order to achieve rapid structural change (Lin, 2015; Lin & Monga, 2010).

In contemporary economies, industrial policy often translates into innovation policies that aim to improve the quality of information flows between actors and institutions, and to strengthen the innovative capacity of firms (Niosi, Bellon, Saviotti, & Crow, 2008), in particular their capacity to absorb knowledge specific to their sector of activity.

To understand the innovation dynamics of an ecosystem, four main items have to be analyzed: knowledge, actors, networks and institutions (Malerba, 2009). The innovation process is embedded in an innovation ecosystem where different actors of innovation (companies, public and private R&D centers, financial companies, administration, etc.) interact with dynamic and systemic relationships supported by exchanges of knowledge and resources (Laperche and Uzunidis, 2007). The state plays a major facilitator's role by solving coordination problems and ensuring the outsourcing of innovation activities (Maghe and Cincera, 2016).

As such, we consider the share of Government investment into the Gross Domestic Expenditures in Research and Development (GERD) to measure the strength of national industrial policy. GERD analysis on an international basis gives five classes (see appendix 3):

1. Serbia, Croatia and Norway all with a percentage above 43%
2. Portugal, Estonia, Spain, Poland, Greece, Romania, Slovakia and Czech Republic, with a percentage between 35 and 41%
3. France, Netherlands, Lithuania, Cyprus and Finland, with a percentage between 29 and 34%
4. Luxemburg, Germany, Austria, Denmark, United Kingdom, Ireland and Sweden, with a percentage between 25 and 28%
5. Bulgaria, Hungary, Slovenia, Switzerland, Belgium and Italy, with a percentage between 13 and 24%.

In the frame of this chapter, we will consider a ranking from 1 to 5, representing a scale from the lowest to the highest level of percentage related to the weight of the government financing into the global GERD. Readers can refer to Annex 2 to find a given country's mark.

3.3.1.2 Variable 2 – National Policy for Sustainable Development

National and territorial transport policy can be assessed through environmental, performance and sustainable development indicators that examine transport policies from an impact perspective.

A sustainable development policy at national level leverages innovation for public transport at local level provided that national government declines measures, indicators and incentives at local level. In most countries, regulation requires any organization to present clear sustainable development indicators to inform public decisions. National government can use these indicators as instruments for negotiation between stakeholders, and local authorities go beyond sectoral approaches, question lifestyles and impulse innovative local transport policies. This negotiation may be more or less incentive going, for example, from the publication of a "bad students" list to financial penalties for cities which do not comply at all.

A rewarded public transport local policy should combine the three following aspects: setting up a transportation system that meets the demand for mobility, minimizing the negative impacts of transportation facilities and travel in terms of resources and pollution, minimization of the associated costs, cost of the service, as well as externalities (noise, accident, congestion, etc.).

The initiatives of local stakeholders are driven by effective national regulations and mechanisms, like the carbon tax as a negative incentive or specific funding for innovation as a positive incentive. National policy for sustainability can also be regulated through taxation on third parties like the dedicated tax chargeable to companies (a percentage of the payroll for the companies, regardless of size and with no exemptions), led in many countries to real diversity in the modes of public transportation. Also, sometimes national governments stay behind local policies implementing only awareness-raising actions.

We think that the way a national government calls on local government for the deployment of a sustainable development policy is a major indicator on the local transport policy. Accordingly, this impacts the weight of regulation in the process of implementing autonomous driving either positively or negatively.

To support this variable, two major indicators can be extracted from the WGI[4]: (1) Government Effectiveness, which captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies, and (2) the Regulatory Quality, which captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development, can be used.

Section 3.3.3 explains how to translate national government position into a ROAD index score.

[4] The worldwide governance indicators – http://info.worldbank.org/governance/wgi/

3.3.1.3 Variable 1 – Local Territories Autonomy

Thinking cities outside any reference to local institutions and the state is an empirically unfounded approach. Obviously, it makes analysis easier and the territories bodies of regulation, instead of states. Recent research shows very clearly the weaknesses of this approach by insisting in particular on the strong dependence of cities in relation to the higher levels of government in terms of their institutional organization, the absence of metropolitan politicians who are becoming independent from the national political apparatuses or the difficulty of the metropolitan representatives to set up public-private partnerships structured at a metropolitan scale (Jouve, 2013).

The political dimension is more complex to understand, as well as the relationships in the multiscale decision-making bodies. Local autonomy is understood as a multidimensional phenomenon, seen as both a right and a capacity. Indeed, as the legalistic approach has shown, local autonomy implies a right and decision-making powers for the management of public affairs, included in a legal framework defining the formal statutes of local governments and the legal protection arrangements of local governments. In relation to the scope of formal functional competencies is the range of services for which local governments are responsible.

Local autonomy is linked, on the one hand, to the financial resources available to local governments independently and, on the other hand, to their administrative capacities and the opportunities they have to create, organize and maintain their political arenas independently. Local autonomy is defined as "the capacity of local governments to make decisions about the services they provide without interference from the centralized government" (Page, 1991).

In this chapter, we propose two methods to assess local autonomy of the analyzed territory: (1) use Keuffer's local autonomy assessment results presented in appendix 1, or, (2) use the European Commission scoring methodology presented in appendix 2. We detail below the two methods.

Keuffer (2017) identified seven dimensions to measure local autonomy as follows.

On this basis, Keuffer (2017) designed a comparative Local Autonomy Index (LAI) and used it to measure autonomy in 39 European countries. Readers can either refer to appendix 1 to find each country's mark. The scoring of the LAI provided five classes[5].

1. A group consisting of the Nordic countries (Finland, Iceland, Denmark, Sweden and Norway) and some central countries (Switzerland, Germany and Poland), all with a local autonomy score of more than 69.55.

[5] This classification is based on the Natural Thresholds algorithm (Jenks). Natural threshold classes depend on the natural pools inherent in the data. The terminals of the classes designated by this method allow to group similar values as best as possible and optimize the differences between classes.

2. Countries with an LAI score in 2014 of between 60.78 and 69.55, namely, Italy, Serbia, France, Bulgaria, Lithuania, Austria, the Czech Republic and Estonia.
3. Countries with an average degree of local autonomy (LAI score between 50.07 and 60.77), i.e. Portugal, Slovakia, Belgium, the Netherlands, Romania, Croatia, Luxembourg, Latvia and Spain.
4. A group of countries with an LAI score in 2014 of between 41.77 and 50.06, i.e. Hungary, Albania, Slovenia, Ukraine, Greece and the United Kingdom.
5. A group of countries where local governments enjoy a low degree of local autonomy (the score for 2014 is less than 41.76), i.e. the countries of southern Europe and those surrounding the Black Sea (Cyprus, Turkey, Georgia, Malta and Moldova) as well as Ireland.

The European Commission also proposed a methodology to measure local autonomy of a local government (Ladner, Keuffer, & Baldersheim, 2015). The authors claim that "*measuring and comparing local autonomy has proven to be a difficult task. Not only are there diverging ideas about the core elements of local autonomy, there are also considerable difficulties to apply specific concepts to different countries*".

By analyzing 39 European countries from 1990 to 2014 with a network of experts on local government assessing the autonomy of local governments of their respective countries the authors identified 11 variables measured on seven dimensions and combined all data to a "Local Autonomy Index" (LAI).

Readers can refer to appendix 2 to calculate or use the methodology proposed by the European commission to calculate the LAI index for one specific region or city.

In the scope of this chapter, the design of our ROAD index needs a ranking from 1 to 5, representing a scale from the lowest to the highest level of local autonomy; Sect. 3.3.3 explains how to translate the LAI given by Keuffer or the LAI resulting from EC scoring into a ROAD index score.

3.3.1.4 Variable 4 – Governance and the Existence of an Integrator at Local Level

The existence of transport and mobility policies has a positive impact for the implementation of new services as well as the existence of public service delegation.

In relation with the general abandon of Keynesian approach and the role of government, in favor of a liberal economy, most of public transport services operations have been transferred to private bodies through regular calls for tender and procurements. In some cases, public bodies still keep control of the services by guaranteeing compliance with operators (Denmark, France, Germany, Switzerland) or decide to let the market play its role (UK). The level of delegation plays an important role for the shift towards innovation.

Stability is important to ensure cohesion of projects on the long term. Generally, the transport governance is composed of an elected body and a technical body, the latter one actually ensures stability.

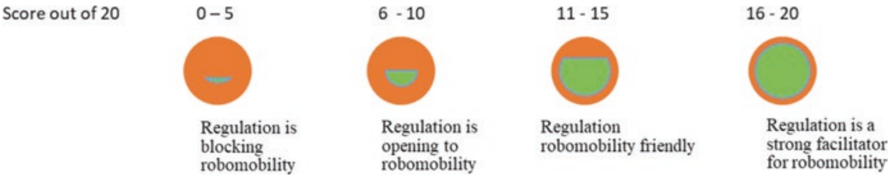


Fig. 3.1 The ROAD index scale

Besides, public transport is very often characterized by multilevel government which allows a better fit to local needs provided local operations are managed by a strong local integrator. The existence of an integrator policy organization at local level implementing local mobility policy has a direct impact on operation efficiency. In that case, the local government can fully delegate operations to the integrator and concentrate on needs anticipation and innovation deployment. But the challenge is to identify what governance arrangements would optimize policy throughout these layers in terms of value.

Governance may be held within four different contexts from the less to the more innovation fostering: (1) no real body of governance; (2) several bodies organizing public transport; (3) operations recently delegate to a local integrator; and (4) operations recently delegate to an advanced integrator; (5) operations recently delegate to an innovation-oriented integrator. Sect. 3.3.3 explains how to translate governance modes into ROAD index scores.

Once the four variables are assessed, we can calculate a global ROAD index whose score gives an evaluation as to whether the analyzed regulatory framework represents a barrier or a facilitator for robomobility. Figure 3.1 pictures the index scale and the meaning of the ROAD index score calculated out of 20. The 4-point scale not only provides a good stratification level but also doesn't allow a neutral point, thereby cities will be clearly positioned in one of the two sides of the spectrum.

3.3.2 Analysis of ROAD Index Variables Applied to Four European Cities

In order to test the ROAD Index, we applied the analysis to four European cities: Copenhagen in Denmark, Lyon in France, Luxembourg City in Luxembourg and Geneva in Switzerland. The context of each city is briefly presented in the following sub-section.

3.3.2.1 Copenhagen, Denmark

In the context of Denmark, the industrial policy is not very developed and has a limited impact on innovative mobility. In terms of environmental performance, Denmark is among the most exemplary countries in terms of Government Effectiveness and Regulatory Quality, but it is considered that there are medium negative or positive incentives. In the context of Denmark, local authorities are well empowered, but road experimentations still depend on national regulation. Consequently, if the local policy for mobility and transport in Copenhagen exists, it is still limited. The approval process of robomobility falls under the national legislative framework, making it very extensive and requiring a lot of documents and safety justification at any stage (more details in Chap. 5).

From January 2019, Copenhagen has an integrator policy body which should have a positive impact in order to integrate innovative mobility solutions in the city mobility plan, as additional means of transportation, and not only as experimental or extra projects.

3.3.2.2 Lyon, France

In France, local authorities can be proactive in terms of local regulations but depend on the national government for laws and schemes. However, there is a current tendency to give more power to local authorities, as reflection of national government withdrawal in public services. The national industrial policy is strong, which has an extremely positive effect on the development of autonomous buses. The centrality of power at the national level is very high, which can have a very positive impact to give general directions either in terms of national policies and/or regulations to support and fasten autonomous buses deployment.

In Lyon, the local policy for mobility and transport is very strong and extends to different cities around the metropolitan area. It has a highly positive effect on autonomous buses projects, allowing the integration of new modes in mobility plans. As detailed in Chap. 10, the governance body, SYTRAL, has been created in 1989 which proved to have an extremely positive impact in order to integrate autonomous vehicles in the city mobility plan, as additional means of transportation, and not only as an experimental or extra project. The contract for the public service delegation to the PTO is renewed every six years: this has strong impacts on the PTO, which has to comply with objectives and KPI determined by the SYTRAL.

3.3.2.3 Luxembourg City, Luxembourg

In the context of Luxembourg, local authorities depend on the national government for laws and schemes and the level of independence is good to have a positive impact on autonomous buses deployment (the mobility and traffic regulation is decided at the local level. Meanwhile, the number of administrative layers is very low (short administrative distance between national and local governments), which can be extremely positive for cities/local governments in terms of autonomy and possible empowerment to authorize and launch experiments and projects (fast decisions and implementation).

In Luxembourg Ville, the centrality of power at the national level is high, which can have a very positive impact to give general directions either in terms of national policy and/or regulation to support and fasten autonomous buses deployment. In the context of Luxembourg, the national industrial policy is strong, which has an extremely positive effect on the development of autonomous buses. In terms of environmental performance, Luxembourg is among the most exemplary countries in terms of Government Effectiveness and Regulatory Quality and it is considered that there are high negative or positive incentives.

In the city of Luxembourg, the local policy for mobility and transport is very strong. It has a highly positive effect on autonomous buses projects, allowing the integration of new modes in mobility plans. The Integrator policy bodies at local level exist for several years and have existed to have an extremely positive impact on the development of e-mobility and thus, in the future, to ease the integration of autonomous vehicles in the global mobility plan, as an additional means of transportation, and not only as an experimental or extra project.

3.3.2.4 Geneva, Switzerland

Due to its particular confederation organization, Switzerland has a very low centrality of power at the “national” level, which can have a very negative impact to give general directions either in terms of national policies and/or regulations to support and fasten autonomous buses deployment The number of administrative layers is very important which could be negative for cities/local governments in terms of autonomy and possible empowerment to authorize and launch experiments and projects. But it is to be noted that these layers have been given relatively high autonomy, which prevents regulation pilling, for example. It shortens the distance between cantons and cities, for example.” by “ But these layers have been given relatively high autonomy and the distance between two layers is shortened by a high level of dialog which allows diverse experimentations. Thus it has a positive effect on the deployment of new systems.

In the context of Switzerland, the industrial policy is not very developed and has a limited impact on innovative mobility. Geneva is independent and therefore can decide on its own regulations and has implemented strong mobility and transport policy. In terms of environmental performance, Switzerland is among the most exemplary countries in terms of Government Effectiveness and Regulatory Quality, but it is considered that there are medium negative or positive incentives. In Geneva, the existence of an integrator, allowing the long term decisions reinforce the capacity to support and fasten autonomous vehicles.

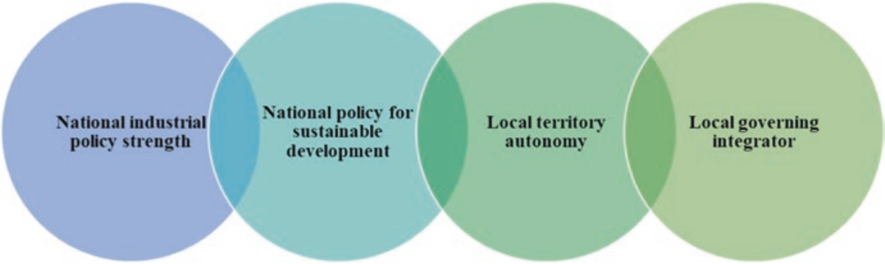


Fig. 3.2 The four variables scoring for the evaluation of the Regulation Openness to Autonomous Driving

3.3.3 Scoring the ROAD Index

Scoring the ROAD index aims at providing an understanding as to whether regulation will boost or limit the deployment of robomobility, for instance: the integration of autonomous buses in the local public transport network that is being regulated.

The four variables we presented in Sect. 3.3.1 are analyzed for each city, and their reality is weighted on a 1 to 5 scale (1 minimum and 5 maximum) (Fig. 3.2).

Scoring the ROAD index allows to assess the regulation framework impact on innovation of each city; the relative approach helps to establish a referential to evaluate the impact of regulation on the city readiness for mobility innovation.

(a) Scoring the Variable “National Industrial Policy Strength”

This variable is scored by analyzing the country’s GERD according to following modalities, (a comparison between several countries is presented in appendix 3)

GERD score	ROADi score	GERD score	ROADi score
0 to 20%	1	41% to 50%	4
21% to 30%	2	Over 51%	5
31% to 40%	3		

(b) Scoring the Variable “National Policy for Sustainable Development”

This variable is scored by analyzing if and how the national government is putting pressure on local government’s policy for sustainable development.

National government position	ROAD index score	National government position	ROAD index score
No national policy for sustainability	1	Medium negative or positive incentives	4
Only awareness actions with proposition for indicators	2	High negative or positive incentives negotiated within a set of indicators	5
Low negative or positive incentive	3		

(c) Scoring the Variable "Local Autonomy"

We propose two ways for scoring this variable. One way is to look for the country's position on local autonomy proposed by Keuffer (2017); appendix 2 presents Keuffer's scores and their translation into ROAD index scores.

The other way is to score local autonomy by using the questions identified by the European Commission as assessment presented in appendix 3. Answering the questionnaire brings out a score of local autonomy (LAI). LAI score ranges between 0 as minimum and 28 as maximum. LAI score is translated on the ROAD index scale from 1 to 5 according to following modalities.

LAI score	ROADindex score	LAI score	ROAD index score
0 to 5	1	16 to 20	4
6 to 10	2	21 to 28	5
11 to 15	3		

(d) Scoring the Variable "Governance"

This variable is scored according to the following modalities:

Governance situation	ROAD index score	Governance situation	ROAD index score
No governance body	1	Advanced local integrator	4
Several local bodies	2	Innovation-oriented local integrator	5
Recent local integrator	3		

Table 3.3 Examples of issues tackled at administrative law level

User requirements issues	Use requirements issue
Does autonomous driving require a special driving license? If so, shall it be national or international? Shall an autonomous vehicle driver ("user") be required to have a driving license at all? Which is the most appropriate terminology between "driver and "user" describing the person guiding the autonomous vehicle?	Do we need any age requirement for autonomous vehicle users? Should we allow autonomous vehicles everywhere? Should it be mandatory on special roads or dedicated lanes? Does autonomous driving have to follow all traffic rules? If an autonomous vehicle violates a traffic rule, does it have to self-report to authorities? Should there be an external indicator on the vehicle when operated on autonomous mode?

Table 3.4 Local autonomy variables

1	Legal autonomy	The formal statutes of local governments and the legal protection arrangements for local governments
2	Political discretion	The general distribution of power and the effective decision-making powers assigned to local governments for the provision of services
3	Scope of delivery	The range of services for which local governments are responsible
4	Financial self-sufficiency	The financial resources available to local governments and the ability to freely decide their sources
5	Organizational autonomy	The free organization of political arenas and administration specific to local governments
6	Non-interference	The extent of freedom left to local governments as part of the control carried out
7	Access	The degree of influence of local governments on political decisions made by higher levels of government

Table 3.3 The ROAD index for the four cities

Cities	Copenhagen	Lyon	Luxembourg	Geneva
Variables				
Local territories autonomy	2	4	3	5
National Industrial policy strength	2	3	2	2
National sustainable development policy and local declination	5	4	5	4
Governance – Integrator policy bodies at local level	3	5	4	5
Road Index per city (score out of 20)	12	16	14	16

3.3.4 The Road Index for the Four European Test Cities

To resume all data presented for the four cities we analyzed, we scored the four variables in Table 3.3 hereafter; this allows us to give an overview of the Road index scoring. Each variable is marked according to the city characteristics we presented in Sect. 3.3.2.

The four cities receive a good score, proving that the regulatory framework their PTOs have to comply with is not only rather open to autonomous driving but can play as facilitator for the integration of autonomous buses into the existing network.

One of the reasons explaining why the ROAD index is the highest for Lyon lies in the public transport governance, which is deeply described in Chap. 10.

Not surprisingly, all those four cities are hosting autonomous buses experimentations mainly within the European AVENUE project (https://h2020-avenue.eu), which is coherent with the good ROAD index they have been granted with our analysis.

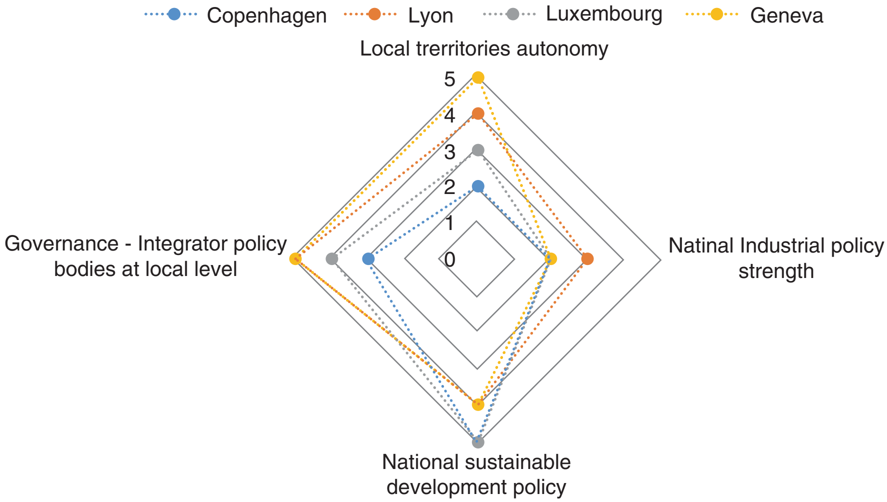


Fig. 3.3 Cities regulatory framework's strengths and weaknesses

Copenhagen obtains the weakest ROAD Index score due to a low local autonomy. This weakness explains why the experimentation that should occur within the framework of the AVENUE project is eventually abandoned during 2020 (Chap. 5 presents for more detailed explanations for this withdrawal).

Figure 3.3 helps to visualize the ROAD Radar comparing in which way cities' characteristics differently concur to the score and which variable could be leveraged to increase the score.

Lyon's strength lies clearly in the existence of an integrator governance body, the centrality of power allowing a national industrial policy which surprisingly functions concurrently with a strong local policy. Lyon's main weakness lies in the thickness of the administrative layers.

On the contrary for Copenhagen, regulatory barriers are due to the weakness of a local power while local policies and local independence could help to turn regulation into a facilitator.

Although well ranked, the city of Geneva lacks a national industrial policy which is due to the federalism of the country that favors local autonomy of Swiss "cantons". Regulation may be considered as facilitator mainly thanks to robust mobility policies made by local authorities. In fact, Geneva is the first city implementing a type of on demand autonomous service (https://h2020-avenue.eu/portfolio-item/geneva).

Luxembourg is a specific case since, due to the small size of the country, the city and the state present an overlapping perimeter that makes less relevant the analysis in terms of local autonomy and national policy.

3.4 Conclusion

Robomobility can be characterized as technology pushed innovation and since its very beginning, regulation has been evolving a step behind technical capabilities and uses. International and regional regulatory organizations try to keep pace with technology and use transformations.

This evolution can be described as a sequential process as described by Hansson (2020). Analyzing the two cases of regulating autonomous vehicles in Sweden and Norway, Hansson (2020) identified multiple regulation modes adjusted within at least three phases. Phase 1 illustrates the existing regulation, which is not adjusted for autonomous vehicles. Phase 2 is the transition phase induced by technological innovations challenging the existing regulation; during this phase, Hansson distinguished three types of co-existing regulation mode: the existing regulatory standards, self-regulation and elements of open method of coordination. Hansson showed how both Sweden and Norway draw on existing regulations when shaping new ones, and at the same time the two countries also shape new regulations based on benchmarks and learning experiences from other countries. Phase 3 leads to the consolidation of the new regulation (Hansson, 2020).

Any stakeholder of the robomobility ecosystem needs to anticipate the future of the regulation's curve to decide today's investments. We think that scanning published regulatory policy does not allow the necessary anticipation, neither does networking with governmental authorities.

Assessing the national regulatory framework can give a stronger perspective on how regulation can facilitate or hinder innovation for mobility like robomobility. Therefore, we designed the ROAD index where the assessment is based on the evaluation of four national variables that influence deeply the regulatory framework openness to innovation. This index was tested within four European cities giving a global appreciation, a comparative analysis and a better understanding of policies that need to be leveraged at national level to make regulation evolve. The ROAD index analysis gives decision makers a tool to become actors on the robomobility regulatory design process.

Appendices

Appendix 1 – Local Autonomy Index by Countries (from Keuffer, 2017)

Country	Index 2014	ROAD index score
Switzerland	79	5
Finland	78,85	5
Island	77,12	5
Denmark	74,49	5
Sweden	74,29	5
Germany	74,16	5
Poland	73,8	5
Norway	72,76	5
Italy	67,05	4
Serbia	66,65	4
France	65,99	4
Bulgaria	65,06	4
Lithuania	64,49	4
Austria	64,35	4
Czech republic	64,17	4
Estonia	62,95	4
Portugal	60,77	3
Slovakia	60,38	3
Belgium	60,02	3
Netherlands	59,17	3
Romania	58,46	3
Croatia	55,86	3
Luxembourg	55,64	3
Latvia	54,23	3
Spain	53,85	3
Hungaria	50,06	2
Albania	49,36	2
Slovenia	48,7	2
Ukraine	47,83	2
Greece	46,86	2
UK	46,31	2
Cyprus	41,76	1
Turkey	38,63	1
Georgia	37,88	1
Malta	37,12	1
Moldavia	35,45	1
Ireland	34,23	1

Appendix 2 – Local Autonomy Assessment from the EC

SELF RULE ASSESSMENT (from Ladner et al., 2015)

Dimensions		Score	Variables
Institutional depth	The extent to which local government is formally autonomous and can choose the tasks it wants to perform	0	Local authorities can only perform mandated tasks
		1	Local authorities can choose from a very narrow, predefined scope of tasks
		2	Local authorities are explicitly autonomous and can choose from a wide scope of predefined tasks
		3	Local authorities are free to take on any new tasks (residual competencies) not assigned to other levels of government
Policy scope	Range of functions (tasks) where local government is effectively involved in the delivery of the services (be it through their own financial resources and/or through their own staff	0–3	not at all; partly; fully responsible of - Education (0-0,3) - Social assistance (0-0,3) - Land-use (0-0,3) - Public transport (0-0,3) - Police (0-0,3) - Health (0-0,3) - Housing (0-0,3) - Caring functions (0-0,3) - Road infrastructure (0-0,3) - Port or airport infrastructure (0-0,3)
Effective political discretion	The extent to which local government has real influence (can decide on service aspects) over these functions	0–3	No, some, or real authoritative decision-making in not at all; partly; fully responsible of - Education (0-0,3) - Social assistance (0-0,3) - Land-use (0-0,3) - Public transport (0-0,3) - Police (0-0,3) - Health (0-0,3) - Housing (0-0,3) - Caring functions (0-0,3) - Road infrastructure (0-0,3) - Port or airport infrastructure (0-0,3)

Dimensions		Score	Variables
Fiscal autonomy	The extent to which local government can independently tax its population	0	Local authorities do not set base and rate of any tax
		1	Local authorities set base or rate of minor taxes
		2	Local authorities set rate of one major tax (personal income, corporate, value added, property or sales tax) under restrictions
		3	stipulated by higher levels of government Local authorities set rate of one major tax (personal income, corporate, value added,
		4	property or sales tax) with few or no restrictions Local authorities set base and rate of more than one major tax (personal income, corporate, value added, property or sales tax)
Financial transfer system	The proportion of unconditional financial transfers to total financial transfers received by the local government	0	Conditional transfers are dominant (unconditional = 0–40% of total transfers)
		1	There is largely a balance between conditional and unconditional financial transfers (unconditional = 40–60%)
		2	Unconditional financial transfers are dominant (unconditional = 60–80%)
		3	Nearly all transfers are unconditional (unconditional = 80-100%)
Financial self- reliance	The proportion of local government revenues derived from local sources (taxes, fees, charges)	0	Own sources yield less than 10% of total
		1	revenues
		2	Own sources yield 10-25% of total revenues
		3	Own sources yield 25-50% of total revenues Own sources yield more than 50% of total revenues

Dimensions		Score	Variables
Borrowing autonomy	The extent to which local government can borrow	0	Local authorities cannot borrow
		1	Local authorities may borrow under prior authorization by higher-level governments and with one or more of the following restrictions: a. golden rule (e.g. no borrowing to cover current account deficits) b. no foreign borrowing or borrowing from the regional or central bank only c. no borrowing above a ceiling, absolute level of subnational indebtedness, maximum debt-service ratio for new borrowing or debt brake mechanism d. borrowing is limited to specific purposes
		2	Local authorities may borrow without prior authorization and under one or more of (a), (b), (c) or (d)
		3	Local authorities may borrow without restriction imposed by higher-level authorities
Organizational autonomy	The extent to which local government is free to decide about its own organization and electoral system	1	Local executives are appointed by higher-level authorities and local authorities cannot determine core elements of their political systems (electoral districts, number of seats, electoral system)
		2	Local executives are elected by the municipal council or directly by citizens
		3	Local executives are elected by the citizens or the council and the municipality may decide some elements of the electoral system Staff and local structures, local authorities: Hire their own staff (0-0,5) Choose their organizational structure (0-0.5) Fix the salary of their employees (0-0.5) Establish legal entities and municipal enterprises (0-0.5)
Score for Self-rule		**0–28**	**The overall self-rule enjoyed by local government in X country (the sum of all the variables above)**

Appendix 3 – GERD Index

This index measures the share of Government funding in the Gross Domestic Expenditure on R&D.

$$\frac{\text{GERD financed by Government in PPP\$}\left(2018\right)}{\text{GERD Total in PPP\$}\left(2018\right)}$$

Country	GERD financed by government	Road index score
Serbia	48%	4
Norway	47%	4
Croatia	43%	4
Portugal	41%	4
Estonia	40%	3
Spain	39%	3
Poland	38%	3
Greece	38%	3
Romania	36%	3
Slovakia	35%	3
Czech Republic	35%	3
Turkey	34%	3
France	32%	3
Netherlands	31%	3
Lithuania	31%	3
Cyprus	30%	2
Finland	29%	2
Luxembourg	28%	2
Germany	28%	2
Austria	28%	2
Denmark	27%	2
United Kingdom	25%	2
Sweden	25%	2
Bulgaria	24%	2
Switzerland	24%	2
Hungary	23%	2
Slovenia	23%	2
Belgium	20%	1
Italy	13%	1

Sources: Unesco institute for Statistics, Science, Technology and Innovation, Expenditure on R&D – GERD Total in PPP$ (2018)

References

ACEA. (2016). The European Automobile Manufacturers' Association. https://www.acea.be/press-releases/article/37-leading-companies-join-forces-in-european-automotive-telecom-alliance

Alter, N. (1993). Innovation et organisation: Deux légitimités en concurrence. *Revue Française de Sociologie, 34*(2), 175–197.

Antonialli, F. (2021). Autonomous shuttles for collective transport: a wordwide benchmark. *International Journal of Automotive Technology and Management, 21*(1/2), 5–28.

Beland, D. (2005). Ideas and social policy: An institutionalist perspective. *Social Policy and Administration, 39*(1), 1–18.

Brenner, N. (2004). *New state spaces : Urban governance and the rescaling of statehood*. Oxford, UK: Oxford University Press.

Brodsky, J. S. (2016). Autonomous vehicle regulation: How an uncertain legal landscape may hit the brakes on self-driving cars. *Berkeley Technology Law Journal, 31*(2), 851–878. Annual Review.

Clergeau de Mascureau, C. (2011). Quelles entraves organisationnelles et institutionnelles à l'innovation dans les organisations bureaucratiques publiques ? *Politiques et Management Public, 13*(2), 141–171.

da Cunha, A. (2005). *Enjeux du développement urbain durable : transformations urbaines, gestion des ressources et gouvernance*. Presses polytechniques et universitaires romandes.

European Union. (2017). EU and EEA Member States sign up for cross border experiments on cooperative, connected and automated mobility. Retrieved June 26, 2019, from https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated

European Union. (2018). On the road to automated mobility: An EU strategy for mobility of the future, 17 May, communication from the commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions European Commission. Brussels. COM(2018) http://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-283-F1-EN-MAIN-P ART-1.PDF

European Union. (2019). Guidelines on the exemption procedure for the EU approval of automated vehicles. Version 4.1, 12 of February 2019, https://ec.europa.eu/docsr oom/documents/34802

European Union Law, Regulation (EU) 2019/2144 of the European Parliament and of the council of 27 November 2019. *Official Journal of the European Union*, 2019., https://eur-lex.europa.eu/eli/reg/2019/2144/oj

Evas, T. (2018). A EU Common Approach to liability rules and insurance related for connected and autonomous vehicles, *European Parliamentary Research Service*, Fevrier, 200p., www.europarl.europa.eu › EPRS_STU(2018)615635_EN

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice, 77*(July), 167–181.

Guilbot, M. (2017). Véhicule connecté, délégation de conduite et responsabilités juridiques. Routes/Roads, PIARC – Association Mondiale de la route, 2017, pp. 47–50. hal-01585204

Hansson, L. (2020). Regulatory governance in emerging technologies: The case of autonomous vehicles in Sweden and Norway. *Research in Transportation Economics*., ISSN 0739-8859. https://doi.org/10.1016/j.retrec.2020.100967.

House of Lords. (2016). Science and technology select committee, connected and autonomous vehicles: The future? Oral and written evidence, www.parliament.uk › documents › science-technology

Ilkova, V., & Ilka, A. (2017). Legal aspects of autonomous vehicles – An overview. In *Proceedings of the 2017 21st International Conference on Process Control, PC 2017, (February)*, pp. 428–433.

Jordana, J., & Levi-Faur, D. (2004). *The politics of regulation: Institutions and regulatory reforms for the age of governance*. Northampton, MA: Edward Elgar Pub.

Jouve, B. (2013). La gouvernance urbaine : vers l'émergence d'un nouvel instrument des politiques ? *Revue Internationale Des Sciences Sociales, 193–194*(3), 387.

Keuffer, N. (2017). L'autonomie locale, un concept multidimensionnel: Comment le définir, comment le mesurer et comment créer un indice d'autonomie locale comparatif? In Revue Internationale de Politique Comparée (Vol. 23, Issue 4). https://doi.org/10.3917/ripc.234.0443.

Ladner, A., Keuffer, N., & Baldersheim, H. (2015). Local autonomy index for European countries (1990–2014). Release 1.0. *Brussels: European Commission*.

Laperche, B., & Uzunidis, D. (2007). Le Système national d'innovation russe en restructuration. *Innovations, 26*(2), 69.

Lin, J. Y. (2015). La politique industrielle revisitée : une nouvelle perspective d'économie structurelle. *Revue D'économie Du Développement, 21*(2), 55.

Lin, J. Y., & Monga, C. (2010). Growth identification and facilitation: The role of the state in the dynamics. The World Bank Development Economics. Office of the Vice President. Policy Research Working Paper 5313.

Li, S., Sui, P-H., Xiao, J. & Chahine, R. (2019). Policy formulation for highly automated vehicles: Emerging importance, research frontiers and insights. *Transportation Research Part A: Policy and Practice, 124*, 573–586.

Malerba, F. (2009). Innovation, industrial dynamics and industry evolution: Progress and the research agendas. *Revue de l'OFCE*, 97 bis(5), 21.

Mordue, G., Yeung, A., & Wu, F. (2020). The looming challenges of regulating high level autonomous vehicles. *Transportation Research Part A: Policy and Practice, 132*, 174–187.

Maghe, V., Cincera, M. (2016). Implementation of innovation policy in a national innovation system perspective: a typology, https://www.oecd.org/sti/072%20-%20NIS%20Typology_MagheCincera.pdf

Niosi, J., Bellon, B., Saviotti, P., & Crow, M. (2008). Les systèmes nationaux d'innovation : à la recherche d'un concept utilisable. *Revue Française D'économie, 7*(1), 215–250.

Overy, A. (2017). Autonomous and connected vehicles: Navigating the legal issues.

Page, E. C. (1991). *Localism and centralism in Europe: The political and legal bases of local self-government* (p. 24 et ss). Oxford, UK: Oxford University Press.

Pinson, G. (2009). Gouverner la ville par projet : urbanisme et gouvernance des villes européennes. Presses de Sciences Po.

Porter, M. (1990). The competitive advantage of nations. *Harvard Business Review, 68*(2), 73.

SAE International. (2019). SAE standards news: J3016 automated-driving graphic update. https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

Savitch, H. V., & Kantor, P. (2002). Cities in the international marketplace : The political economy of urban development in North America and Western Europe.

The United Nations Economic Commission for Europe. (2019a). The united Nations economic commission for Europe automated driving @UNECE. Retrieved June 20, 2019, from http://www.unece.org/index.php?id 42509.

The United Nations Economic Commission for Europe. (2019b). ECE/TRANS/WP.1/167. Report of the global forum for road traffic safety on its seventy-eighth session. 25–29 march 2019. https://www.unece.org/trans/roadsafe/wp1rep.html

Urban Mobility Company. (2020). French Mobility Orientation Law. https://urbanmobilitydaily.com/your-guide-to-the-french-mobility-orientation-law/

Weber, M. (1968). In G. Roth & K. Wittich (Eds.), *Economy and society (1922)*. New York: Bedminster P.

Chapter 4
Economic Assessment of Services with Intelligent Autonomous Vehicles: EASI-AV

Fabio Antonialli, Sylvie Mira-Bonnardel, and Julie Bulteau

Abstract While most of the current research on autonomous public transport focuses on improving operational and technical aspects, as well as tackling policy and user behavioral factors, the integration of autonomous buses into public networks is mainly dependent on costs and breakeven points (both for operators and local governments). Research quantifying costs and return on investment specifically in academic settings are sparse. This chapter aims to introduce a simulation tool: EASI-AV, designed as a decision-making tool to support public policies on the decision of implementing innovative mobility services. EASI-AV proposes to (1) assess the global economic impacts of deploying fleets of AVCTs in comparison with traditional public transport modes, and (2) help local authorities to build scenarios integrating autonomous buses into their public network and imagine new business models. The simulation is based on the Total Cost of Ownership (TCO) approach and includes four aspects that may be used independently: the fleet size dimensioning, the TCO calculation with internal costs and local externalities, the business model simulation, and the global impact assessment in comparison with other transport modes. EASI-AV was tested with real data from pilot sites, and the results prove it to be fully relevant.

F. Antonialli (✉)
Laboratoire de Tribologie et Dynamique des Systèmes (LTDS), École Centrale Lyon, Écully, France
e-mail: fabio.antonialli@ec-lyon.fr

S. Mira-Bonnardel
École Centrale Lyon, Écully, France
e-mail: sylvie.mira-bonnardel@ec-lyon.fr

J. Bulteau
University of Versailles Saint-Quentin-en-Yvelines, University of Paris-Saclay, Guyancourt, France
e-mail: julie.bulteau@uvsq.fr

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_4

Keywords Autonomous vehicles · autonomous shuttles,; public transport · economic impact assessment · Total Cost of Ownership (TCO)

4.1 Introduction

National and city governments are expected to redesign public transport in order to better cope with the increase in urbanization as well as the growing negative externalities of mobility, such as congestion, pollution, and noise. Furthermore, policy makers are quite aware that public transport is a key element for the economic development of a region and the quality of life of its citizens and voters.

Meanwhile, 15 major cities around the world are starting to ban cars. The idea of a car-free city is not without its challenges, since cars remain a preferred method of transportation for many urban commuters. Therefore, public authorities need to define new strategies for the development of efficient public transport based on different importance criteria for their regions, such as their topography, citizens' needs and desires, economic barriers, environmental concerns, historical development, etc. On the other hand, new transport technologies and services are emerging with promising alternatives for supporting regional public transport development strategies.

As stated by Attias (2017), this revolution of urban areas will likely occur by the arrival of autonomous collective vehicles like buses or shuttles, thus building a new paradigm of urban mobility and smart cities. If successfully deployed, Autonomous Vehicles for Collective Transport (AVCTs) can provide flexible and cost-efficient solutions for serving both peak and off-peak demand by driving parallel and, as feeders to mass transit trunk lines (Ainsalu et al., 2018; Merat, Madigan, & Nordhoff, 2017).

In fact, estimates presented by RethinkX (2017) show that by 2030, 95% of the passenger miles traveled will be served by shared fleets of on-demand autonomous electric vehicles, in a new business model of Mobility-as-a-Service (MaaS). Furthermore, as pointed out by ARK Invest (2017), this future market offering will cost consumers $0.35 cents per mile (roughly half of the all-in cost car owners pay to drive today), and thereby it should exceed 10 trillion dollars in sales by the early 2030s.

Urban centers could strongly benefit from the introduction of AVCTs (Ainsalu et al., 2018). For the authors, besides being the first- and last-mile connection to mass transit, AVCTs could compete with automobiles by price and be more effective than traditional public transport buses (by taking 15 instead of 150 passengers), being on-demand instead of on-schedule, and moving on flexible routes instead of fixed ones.

Much of the effort dedicated to the implementation of AVCTs focused on improving their operational and technical aspects, as well as policy and behavioral factors that will allow successful deployment and user/societal uptake (Gandia et al., 2018;

Merat et al., 2017); however, their market penetration rate is dependent on costs (direct and indirect) and return on investment (Ongel et al., 2019), with that, research quantifying the costs and benefits of AVCTs, specifically in academic settings are sparse. As pointed out by (Henderson, Veder, Li, & Johnson, 2017), most of the research has focused on the cost impact of autonomy on taxis and other ride sourcing services for vehicles up to five passengers.

In this sense, the present chapter aims to fill this gap by introducing a simulation tool to assess the economic impacts of deploying fleets of autonomous vehicles for collective transport and different implementation scenarios. Our ambition with this decision support tool is to provide an objective and quantitative toll to evaluate public policy scenarios on implementing innovative public transport services like autonomous collective vehicles.

Our tool, kindly named as EASI-AV, proposes an **E**conomic **A**ssessment of **S**ervices with **I**ntelligent **A**utonomous **V**ehicles.

EASI-AV is able to provide: the fleet dimensioning, calculate the total cost of ownership, and the costs of local externalities of the service. EASI-AV was designed with the objective of helping policy makers in cities, regions, or even Public Transport Operators (PTOs) and others that may be interested in implementing services with AVCTs (like companies or university and hospital campuses). EASI-AV has been tested on pilot cases in Luxembourg, Lyon, Geneva, and Copenhagen, and the results show that the algorithms are coherent and yield good results.

This chapter is structured as follows. Section 4.2 brings the theoretical framework by presenting an overview of AVCTs economic impact assessment for the applicative domain. The tool, EASI-AV, is presented in Sect. 4.3 with an example of its application with empirical data from a pilot site. In Sect. 4.4, we present a holistic view on the economic impact evaluation, on business models for AVCTs and the limitations of our tool. Section 4.6 concludes on the study.

This chapter is a parallel study alongside the AVENUE project. The Autonomous Vehicles to Evolve to a New Urban Experience project (AVENUE), is an EU funded project which aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of AVCTs on mixed-traffic conditions. Providing innovative services, like door-to-door and multimodal transportations, in low to medium demand areas of four European demonstrator cities: Geneva, Lyon, Copenhagen, and Luxembourg (AVENUE, 2018).

4.2 Theoretical Framework: Autonomous Mobility Impact Assessment

4.2.1 Autonomous Vehicles for Collective Transport (AVCTs)

As stated by Mira-Bonnardel and Attias (2019), the most revolutionary impact of Autonomous Vehicles (AVs) will probably be on collective public transport with the introduction of on-demand mobility that will deeply impact the urban commute and its business models (see Chap. 1 for further in-depth view). Therefore, AV manufacturers have been leaning into intermediate sized electric buses with an average capacity of 15 passengers, that allows them to serve either fixed or on-demand routes offering microtransit services, or acting as a complement to high capacity transit systems by covering the first- and last-mile parts of the commute (Harris, 2018; Ongel et al., 2019).

Thereby, AVCTs have progressed through conceptual design, fundamental research, and technological development, and are now facing commercial applications (Zhang, Jenelius, & Badia, 2019). Current AVCTs fall into the levels 3 and 4 of vehicular automation as proposed by SAE (2016), and are already being tested in various parts of the world both on dedicated lanes and in mixed traffic, always respecting traffic rules and local policies: with maximum speeds between 15 and 25 km/h and with a human operator on board for fallback if automation fails, as required by current regulation.

With this, a significant group of new companies have been implementing pilot projects with AVCTs (Clausen, 2017; Mira-Bonnardel & Attias, 2018), and in order to better understand the panorama of these pilot projects, Antonialli (2021) conducted an extensive worldwide benchmark identifying a total of 176 projects (among finished, on-going and, yet-to-start) that unfold in 142 cities, spread over 32 countries, being enabled by 20 different autonomous shuttles manufacturers.

Results have shown an European lead on both the number of experimentations (101 projects – 57.39%) and manufacturers (9 out of the 20), with highlights to the French startups Navya and Easymile, which are the global leaders when it comes to manufacturing and deployment of AVCTs worldwide (Antonialli, 2021). In addition, by analyzing the prevailing business models of the experimentations, the author concluded that AVCTs are offered by PTOs as a transport solution to citizens of a given city/region/area to either serve as first- and last mile commute (50.28%) or microtransit (49.72%).

A second in-depth study, carried out by Mira-Bonnardel, Antonialli, and Attias (2021), analyzed more deeply three main European Projects with AVCTs (CityMobil2, Sohjoa, and Gateway) with the aim of identifying their most relevant social and economic results. Their main academic findings showed varied and extensive results on consumers' behavior, acceptance, and willingness to use, as well as studies with the aim of advancing technical aspects of the service and the legal barriers to overcome. However, as the authors stated, robust results on economic aspects were not addressed or were not disclosed on the projects' publications. The few results found were mainly concerned with users' willingness to pay, and the potential to reduce fares (mainly due to the lack of a human driver).

Although results shown by Antonialli (2021) and Mira-Bonnardel et al. (2021) made it clear that the experiments with AVCTs did not address or disclose comprehensive results on the economic assessment of deployments, there has been important academic advances (not directly linked to the aforementioned experimentations) addressing the costs and benefits of implementing AVCTs. The next subsection further details the theoretical premises on economic assessment for AVCTs.

4.2.2 Economic Impact Assessment of AVCTs

With AVCTs expected to be an accepted technology by 2030 (Litman, 2018), their market penetration rate is dependent on costs. By not requiring a driver and with expected lower energy consumption due to smoother driving, AVCTs may have lower operating costs than their human-driven counterparts (Fagnant & Kockelman, 2015); however, the current imbedded autonomy pack constitutes the major cost components – with LIDARs, sensors, cameras, processing unit, V2X equipment ranging from around 25,000 to 30,000 dollars, not to mention that AVCTs are generally equipped with an electric battery and powertrain, which also increases costs, and reduces the overall lifecycle of the product to currently around 5 years (Ongel et al., 2019).

On the other hand, it is expected that the prices of the automation pack as well as battery prices will go down with time and hence AVCTs may become cost effective compared to conventional vehicles in the long term (Bansal & Kockelman, 2017; Catapult Transport Systems, 2017; KPMG, 2015).

In this sense, cities and PTOs should consider the costs and benefits of implementing a public transport service using AVCTs over traditional services, and several recent studies have sought to provide answers to these demands.

Kalakuntla (2017) carried out a prospective comparative study of costs and benefits of fleets of AVCTs versus traditional regular diesel buses for the city of Austin (Texas, USA) with the aim of guiding Public Transport Operators (PTOs) on whether AVCTs are feasible or not. The author concluded that AVCTs can save PTOs' from capital & operational costs, reduce the environmental effects, and increase the quality of life of the people.

The study carried out by Henderson et al. (2017) aimed at finding useful and efficient ways to use AVCTs in the campus of the Ohio State University (USA), the authors conducted an analysis to compare the current fleet of traditional vehicles used on campus to the costs of purchasing and maintaining a fleet of AVCTs (in their case the shuttle Olli from Local Motors). It was concluded that the autonomous shuttle exceeded the fleet of traditional vehicles in several categories – cheaper cost/mile, fewer carbon emissions/mile (0.91 lbs), and lower annual maintenance costs

($600/yr) – however, the autonomous shuttle was currently not cost-effective due to its high initial price relative to traditional shuttles.

Bösch, Becker, Becker, and Axuausen (2018) carried out a substantial cost-based analysis comprising a bottom-up calculation of the cost structures (including besides the fixed costs, the overhead costs of shared services) for different types of AVs in various operation models, such as: dynamic ride-sharing, taxi, shared vehicles fleets, and AVCTs. The authors stated that their methodology allows determination of different cost components' importance and differentiation of vehicle automation effects on individual cost components. Their results showed that more than half of AVs fleets' operating costs will be service and management costs. Furthermore, they've concluded that autonomous driving technology will allow taxi services and buses to be operated at substantially lower costs, even more cheaply than private cars.

And lastly, the study from Ongel et al. (2019) aimed at determining the Total Cost of Ownership (TCO) of AVCTs and comparing them to regular internal combustion engine buses and mini-buses. Their TCO analysis included three major cost components: acquisition costs, operating costs, and end-of-life costs. Their simulations have shown that although the acquisition costs of AVCTs are higher than those of conventional buses, they can reduce the TCO per passenger-km up to 75% and 60% compared to conventional mini-buses and regular buses, respectively.

Although bringing several promising and interesting results regarding the economic feasibility of services with AVCTs, none of the aforementioned studies proposed a holistic methodology for dimensioning and assessing the economic impact of AVCTs services which could be easily applied by decision makers – such as city and regional governments and other interested stakeholders – in the economic evaluation and decision of whether or not implementing services with AVCTs.

Therefore, we designed a simulation tool EASI-AV that helps to assess the economic impact of AVCTs integration into public transport networks and to simulate different scenarios by allowing the users to play with cost variables as well as revenue variables. In the next section, we explain how EASI-AV has been designed and how it works.

4.3 The EASI-AV Simulation Tool

4.3.1 EASY-AV Design Methodology

The **E**conomic **A**ssessment of **S**ervices with **I**ntelligent **A**utonomous **V**ehicles (EASI-AV) tool was developed as a support tool to assist decision makers in cities, as well as transport operators, and other organizations to estimate the economic assessment of implementing a service with AVCTs.

EASI-AV has been developed within the European project AVENUE. We worked with the transport operators in charge of the collective transport network and responsible for the demonstrators in the four cities in the project (Copenhagen, Geneva, Lyon, and Luxembourg). We collected their data on the autonomous service as well as on traditional services to test the tool and check the reliability of its algorithms.

The EASI-AV tool was firstly designed using a spreadsheet software and manual data entry with automated calculation. By the time this chapter was published, the EASY-AV tool was being designed as a web application, including automated data collection (such as geolocation and traffic data). Once finished, the EASI-AV application is due to be on open access on the AVENUE project website.

4.3.2 EASY-AV Structure

The EASI-AV tool provides different types of assessments in a comparative manner (between the shuttle and different transport modes), such as the Total Cost of Ownership (TCO) – including investment costs and operational costs, the Local Impact of externalities as well as the Global Impact assessment – with business model and breakeven assessment.

As shown on Fig. 4.1 and on the paragraphs that follow, the EASI-AV is composed of five different parts that may be carried out sequentially or independently according to the needs of the user.

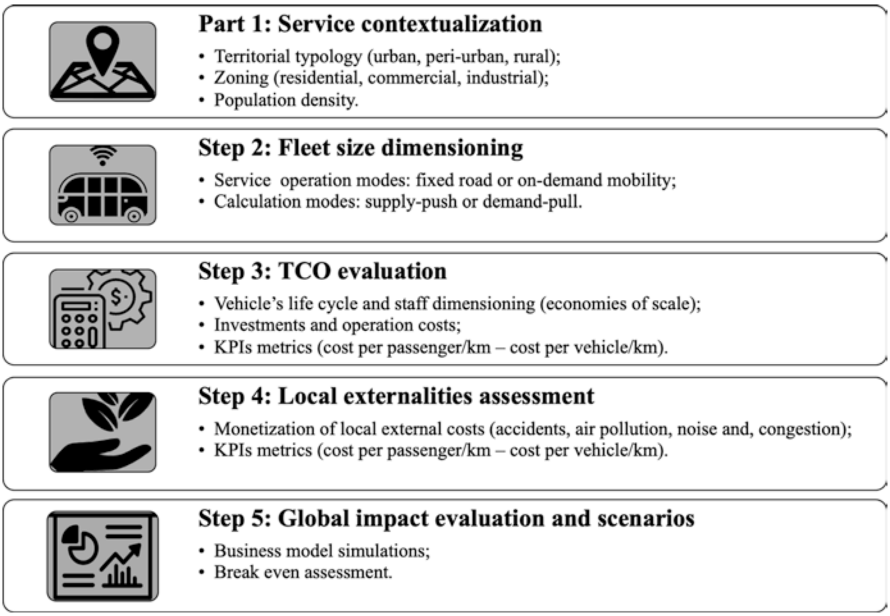


Fig. 4.1 EASI-AV analyses portfolio

4.3.2.1 Part 1 – Service Contextualization

This part consists in qualitatively defining the local context envisioned for the new services with AVCTs. Contextualizing the service helps to build more accurate scenarios and allows decision makers to have a holistic view of the service context to be implemented. EASI-AV helps to properly frame the territorial typology (urban, peri-urban, rural), the zoning (residential, commercial, industrial or mixed areas), define the public transport supply (if there is already existing public transporting the area) and the area's population density as well as surface area and extension of roads. Data for contextualization can be either entered by the user or automatically extracted online.

4.3.2.2 Part 2 – Fleet Size Dimensioning

As detailed on Table 4.1, EASI-AV proposes four alternatives for the fleet size calculation, that are guided by two main drivers: 1) service type (supply-push or demand-pull), and 2) road environment (fixed-roads or on-demand). EASY-AV allows the fleet size to be calculated for all combinations of service type/road environment.

Once the category is selected, decision makers enter data on selected cells if they work with the spreadsheet tool or ask for data collection online if they work on the web application. In Sect. 4.4.2, we develop how the four combinations are introduced in mobility scenarios.

For road environment 1, the fleet size dimensioning is based on traditional fleet size calculations. Besides the usual general parameters characterizing the territory (route length, average speed, layover time, capacity, etc.) and specific parameters characterizing local mobility uses (percentage of public transport users in the area or numbers of operating hours per day), we considered some other specific for parameters as a way of leading to a finer calculation, such as the average operational speed (taking into account the idle time on each stop), as well as the battery autonomy and its charging time (which allows us to make a time differential to integrate in the calculation for how long a vehicle will be out of service to recharge). Simple algorithms compute these data and propose an optimum fleet size.

Road environment 2 is more complex since the algorithms have to evaluate how many kilometers the vehicle may drive across the serviced area to comply with any users' demand for any direction at any time. Key elements of calculation in that

Table 4.1 Fleet size calculation options array

	Service type 1 Demand-pull (S1)	Service type 2 Supply-push (S2)
Road environment 1 Fixed road (R1)	R1S1	R1S2
Road environment 2 On-demand (R2)	R2S1	R2S2

option are the passenger waiting time (i.e. how long should a requester wait before a vehicle arrives), and the maximum distance between the requester and the vehicle at the time of the request. After computing these elements in addition to all elements taken into account for option 1, EASI-AV proposes an optimum fleet size.

For Service type 1 (demand-pull), EASI-AV proposes calculations via demand side, that is: for the cases where the demand for mobility is known. Three calculation scenarios are proposed depending on the degree of knowledge of data concerning the existing transport demand (the number of passengers or the expected percentage of passengers during the peak and off-peak hours, etc.). The objective is to offer a flexible, modular tool depending on the transport demand and/or the future transport service offer.

For Service type 2 (supply-push), the tool offers calculations via supply, where demand on public transport is unknown or the service will be offered as a new transport offering in a supply-pushed strategy. Figure 4.2 illustrates the spreadsheet data entry for R1S1 and R1S2.

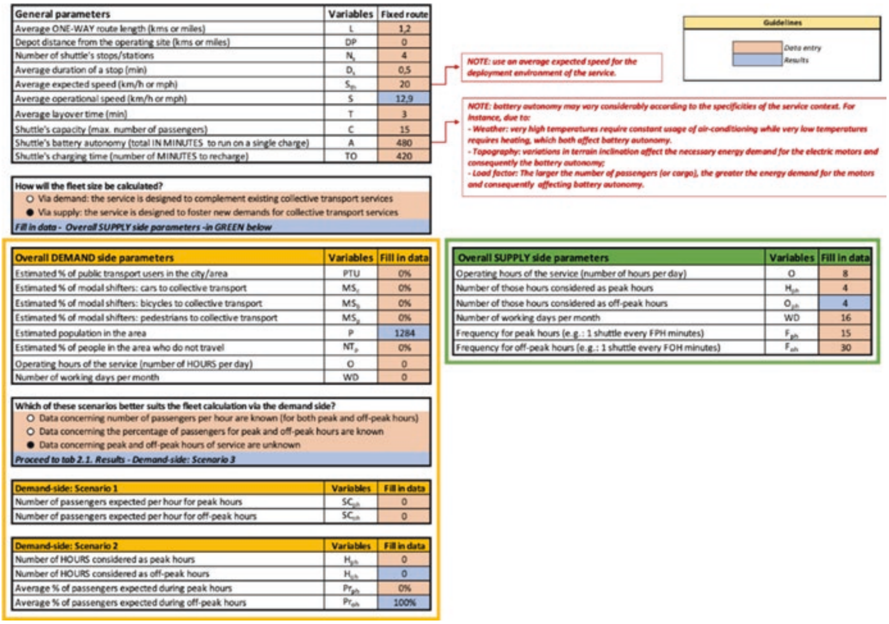


Fig. 4.2 Fleet size calculation data entry for R1S1 and R1S2

4.3.2.3 Part 3 – TCO Evaluation

The TCO evaluation part may be used as the follow up of part 2 (fleet size dimensioning), or if the fleet size is already known, it may be started with entering the current fleet size the users seek to evaluate.

For this part, questions about the lifetime of the vehicles as well as the number of on-board safety drivers and off-board supervisors are asked. The former will allow the calculation of the depreciation, while the last two will allow a better characterization of the operating costs and possible economies of scale in terms of personnel.

The main internal costs are investment costs (or capital expenditures – CAPEX) and operations expenditures (OPEX), both have to be determined. Once all costs are registered, EASY-AV calculates the costs per passenger/km and per vehicle/km as well as other indicators. These ratios will be used afterwards for a detailed comparison between other transport modes.

To help the user, we created a list of the most relevant Capex and Opex cost sources that are explained on a specific side-document and via drop-down menus for the web application. In order to integrate economies of scale, the user can choose if the cost applies to a single vehicle or to the entire fleet (e.g., feasibility study is not a cost per vehicle, whereas acquisition costs is a cost per unit).

In some cases, it is possible that the people who are filling out the tool do not know the exact cost values for the autonomous shuttle, being a new (and until now scarcely implemented technology), data about costs and financial values may not be easily accessible and foreseeable for everyone. For these cases, we provide the option of using the standard costs (determined based on the average results obtained in the AVENUE project). All that needs to be done is choose the button to use generic costs.

4.3.2.4 Part 4 – Local Externalities Assessment

At both local and global scales, public actions are considered in terms of sustainability. In this regard, the transport sector is no exception (Bulteau, 2016). The objective of policy-makers is to reduce negative externalities of transport for the community, such as congestion, environmental pollution, and accidents. This is why the economic assessment has to take into account externalities generated by the transport service implemented in the territory.

In the EASI-AV tool, several sources of external costs for the cities are considered: congestion, accidents, air pollution (NOx and fine particles), and noise. The monetized values of these externalities come from the Handbook of the externalities of transport (European Commission, 2019) being adjusted for inflation for the year 2020 and adapted to fit AVCTs. To get the results for externalities valuation, all that needs to be done is select the country of where the shuttle will be deployed. Everything else is automatically calculated. A comparative analysis is provided between the external costs generated by the fleet size of shuttles and different modes of transport (see Fig. 4.5).

It is worth noting that since this assessment is based on secondary data from the Handbook of externalities of transport, the analysis is only available for the European countries listed in the handbook.

4.3.2.5 Part 5 – Global Impact Evaluation and Scenarios

The implementation of autonomous vehicles may open the way for new business use cases and new business models. Different funding sources may be explored along with the traditional subsidies and ticketing because autonomous fleets may be more flexible and more customizable than a traditional fleet. EASI-AV can help to monetize all business scenarios and bring a comparative analysis with alternative mobility modes.

For instance, scenarios may be combined with passenger ticketing at peak hours as well as with goods delivery financed by freight forwarding companies during off-peak hours. They can also differentiate week-days with subsidized workers traveling and weekends with paid tourists (sightseeing). In addition, passengers may be willing to pay more than the standard ticket price for customized on-demand offers while for fixed-routes, the trip may have the same price of the local ticket, included on monthly or weekly passes, or even be free of charge for the local population commuting to a mass transit mode.

Because use cases and their revenue models are still to be envisioned, EASI-AV proposes different revenue scenarios varying from ticketing, subsidies, financing from companies, from tour operators, and from other different public sources (such as ministry of health, etc.). In the tool, decision makers are asked to give an estimated value of the percentage of the annual operation costs that are covered by each revenue source.

Since the objective of EASI-AV is to evaluate the impact of the introduction of autonomous vehicles, decision makers get to use the comparative approach between AVCT and any other public transport mode they would like to choose to be their baseline vehicle for comparison.

The tool also gives results for the TCO comparison set of main indicators for both the AVCTs and the chosen baseline vehicle (such as: cost per passenger/km, cost per vehicle/km, one-way cost per passenger/km and one-way cost per vehicle/km, etc.).

4.3.3 EASI-AV Application on a Test Pilot in Luxembourg

In this section, we present the tool in action exemplified with real data from a pilot site in the neighborhood of Pfaffenthal in Luxembourg City.

4.3.3.1 Part 1 – Service Contextualization

The Pfaffenthal area of 0.38 km^2 has a total population of 1284 inhabitants, and is not served by the city's traditional public transport network. In June 2018, as part of the European Commission funded project AVENUE (AVENUE, 2018), the local transport operator (Sales-Lentz) implemented in the area a 1.2 km fixed-looped route (with four stops) serviced by two Navya ARMA shuttles to run free of charge to passengers every Tuesday, Thursday from 12h00 to 20h00 and every weekend and public holidays from 10h00 to 21h00.

Regarding the data entry, it is worth emphasizing that data characterizing the context can be filled in manually by the users on the spreadsheet, while for the web application, extraction algorithms can collect data concerning surface and population when the user enters identification geographic points.

4.3.3.2 Part 2 – Fleet Size Dimensioning

EASI-AV was applied to Pfaffenthal configuration (R1S2 from Table 4.1) and the calculated results corroborate the real number of two shuttles implemented by Sales-Lentz in their trials, proving the accuracy of the tool (a similar validation was also carried out in the AVENUE testing sites in Lyon, Geneva, and Copenhagen).

Besides the total expected fleet size, the results shown on Fig. 4.3 also give some other interesting metrics and KPIs for decision makers (such as: number of passengers for peak and off-peak hours, frequency of shuttles, maximum total of kilometers per shuttle, and so on).

SUPPLY SIDE		
Number of passengers for peak hours:	60,00	users/hour
Number of passengers for off-peak hours:	30,00	users/hour
Fleet size for peak hours calculation:	1,78	shuttles
Fleet size for off-peak hours calculation:	0,89	shuttles
Maximum total of kilometers per shuttle		
Daily:	43,27	kms
Monthly:	692,28	kms
Yearly:	8307,38	kms
TOTAL FLEET SIZE*:	**2**	**shuttles**

* value rounded off to the nearest whole number

Fig. 4.3 Fleet size calculation results for Pfaffenthal via the R1S2 configuration

4.3.3.3 Part 3 – TCO Evaluation

As exemplified with data for the Pfaffenthal pilot site, many indicators are given as results, such as the total CAPEX and OPEX both for the single vehicle and for the fleet. Due to confidentiality, we cannot present all financial data from the experimentation site, but Fig. 4.4 gives an overview of the results by summarizing the main sources of CAPEX, OPEX as well as the revenue sources percentage needed to cover the yearly OPEX for both the baseline vehicle and for the shuttle.

The most important CAPEX source for both the shuttle as well as for the baseline bus was vehicle acquisition (87.73% and 98.91%, respectively). Regarding OPEX, the most relevant cost source for the baseline vehicle is costs with personnel (that is: drivers' salaries), representing more than half of the total OPEX (66.51%), corroborating the results found by Bösch et al. (2018). For the current stage of deployments with AVCTs, costs with personnel are also representative (32%), in a sense that the legislation still requires a safety driver onboard the vehicles. However, the most relevant operational cost for the shuttles is depreciation (41%), as stated by Ongel et al., (Ongel et al., 2019) this is due to the fact that the current life cycle of these vehicles are significantly shorter, averaging 5 years versus the 15 for traditional buses. This is mainly due to the fast pace of technology evolution of sensors, cameras, and the aging of the battery.

Regarding the revenues, as of March 1, 2020, the government of Luxembourg made free all public transport in the country (Lo, 2021), thereby, for traditional buses, 100% of the transport is subsidized, while for the shuttle, by being a pilot site partially funded by the AVENUE project, part of the funding comes from subsidies (around 70%) and part of it comes from the EC (around 30%).

Taking all these elements into account, it can be seen that today the CAPEX needed for deploying services with AVCTs is not much higher than those needed for a traditional bus (in the case of Pfaffenthal pilot site, it is only 7% more for the entire fleet).

On the other hand, the annual operating costs for AVCTs are still higher (37% for the fleet and 26% for a single vehicle) when compared to the baseline, thereby, our tool corroborates the findings of Henderson et al. (2017) since autonomous shuttles are indeed currently not cost-effective relative to traditional buses. Thereby taking into account the TCO calculation, results from Pfaffenthal estimate a current cost per passenger/km of 3.59 € versus 1.57 € for the baseline bus.

However, as technology and legislation evolves, it is expected that in the coming years the life cycle of shuttles will increase (hence reducing the depreciation costs) and an onboard safety driver will no longer be needed (thereby drastically reducing the costs with personnel), which assures that our tool is also aligned with the results of the prospective studies carried out by Fagnant and Kockelman (2015), Bösch et al. (2018) and, Ongel et al. (2019).

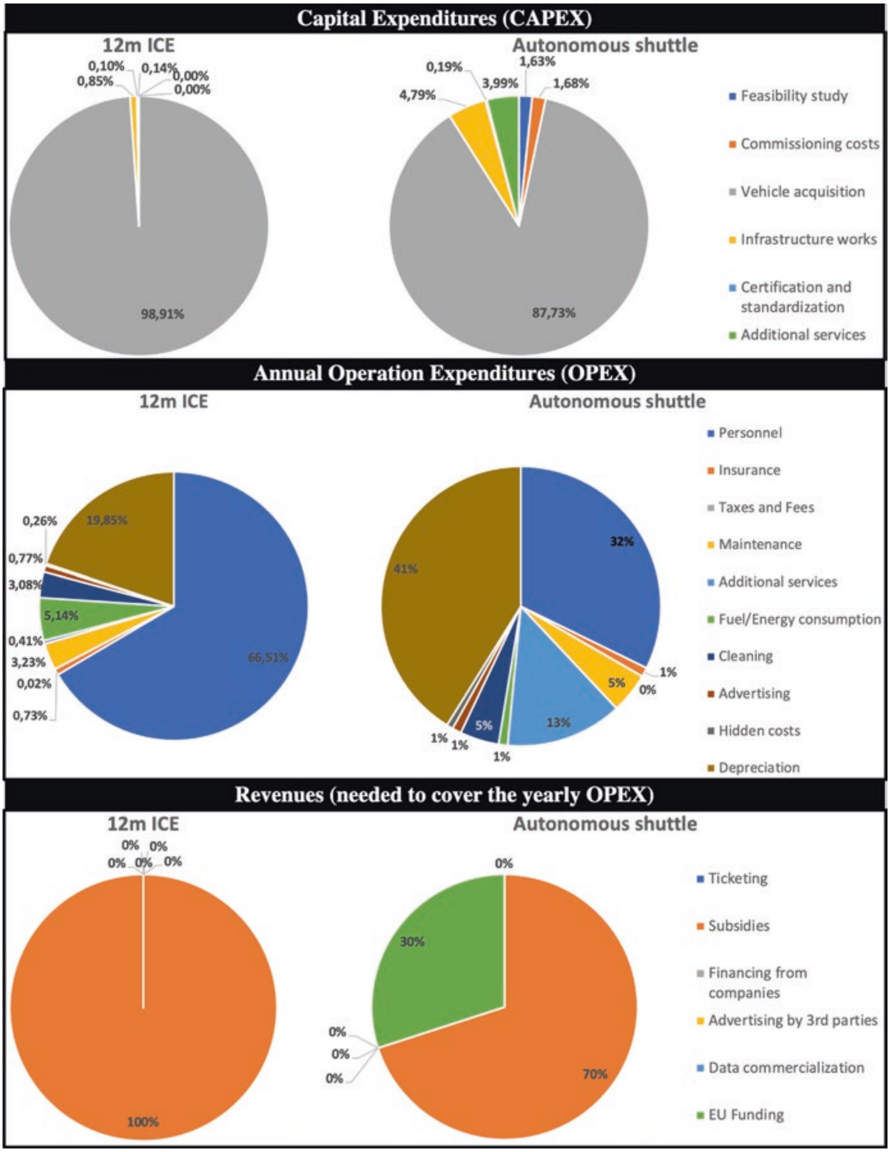
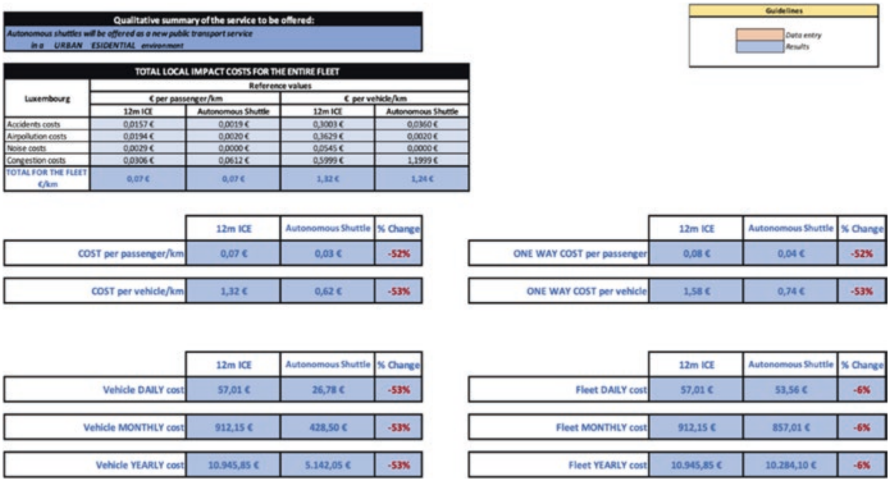


Fig. 4.4 Summary of TCO results for Pfaffenthal pilot site

4.3.3.4 Part 4 – Local Externalities Assessment

As shown on the results of Fig. 4.5, EASI-AV provides a cost per passenger/km and a cost per vehicle/km for each externality studied and, therefore, the total cost of the externalities for the shuttle fleet and the modes of transport taken in comparison. This results in several cost indicators, such as the vehicle daily, monthly, and yearly



Qualitative summary of the service to be offered:
Autonomous shuttles will be offered as a new public transport service in a URBAN ESIDENTIAL environment

Guidelines
Data entry
Results

TOTAL LOCAL IMPACT COSTS FOR THE ENTIRE FLEET				
Luxembourg	Reference values			
	€ per passenger/km		€ per vehicle/km	
	12m ICE	Autonomous Shuttle	12m ICE	Autonomous Shuttle
Accidents costs	0,0157 €	0,0019 €	0,3003 €	0,0360 €
Airpollution costs	0,0194 €	0,0020 €	0,3629 €	0,0020 €
Noise costs	0,0029 €	0,0000 €	0,0545 €	0,0000 €
Congestion costs	0,0306 €	0,0612 €	0,5999 €	1,1999 €
TOTAL FOR THE FLEET €/km	0,07 €	0,07 €	1,32 €	1,24 €

	12m ICE	Autonomous Shuttle	% Change
COST per passenger/km	0,07 €	0,03 €	-52%
COST per vehicle/km	1,32 €	0,62 €	-53%

	12m ICE	Autonomous Shuttle	% Change
ONE WAY COST per passenger	0,08 €	0,04 €	-52%
ONE WAY COST per vehicle	1,58 €	0,74 €	-53%

	12m ICE	Autonomous Shuttle	% Change
Vehicle DAILY cost	57,01 €	26,78 €	-53%
Vehicle MONTHLY cost	912,15 €	428,50 €	-53%
Vehicle YEARLY cost	10.945,85 €	5.142,05 €	-53%

	12m ICE	Autonomous Shuttle	% Change
Fleet DAILY cost	57,01 €	53,56 €	-6%
Fleet MONTHLY cost	912,15 €	857,01 €	-6%
Fleet YEARLY cost	10.945,85 €	10.284,10 €	-6%

Fig. 4.5 Local externalities analysis results

external costs. By being electric, the results for the shuttles in Pfaffenthal show a drastic reduction in the local external costs for the service.

4.3.3.5 Part 5 – Global Impact Evaluation and Scenarios

The four previous parts conduct a picture of a global impact assessment for decision making concerning the implementation of autonomous mobility. In Luxembourg, Fig. 4.6 shows that the revenue model is not diversified yet but the tool is ready to let decision makers re-imagine the business model future of their autonomous fleet.

Revenue data are used to calculate financial ratios like the breakeven point or the net present value; those ratios quantify the cost-benefit analysis and contribute to the decision-making process for investors as well as for policy makers (if different).

Since investors or policy makers need to choose how to implement multimodality, EASI-AV systematically gives tables and indicators to compare the impact of autonomous services with other collective transport modes options.

4.4 Economic Impact Evaluation: a Holistic View

4.4.1 The Scope of Economic Impact Evaluation

The future public transport in urban and suburban areas should be safe, rapid, economic, ecological, and personalized. Technology progress of robomobility supports the development of new services that could transform the simple ride into a high

	REVENUE SOURCE	12m ICE	%	Autonomous Shuttle	%
1.	Ticketing		0%		0%
2.	Subsidies		100%		70%
3.	Financing from companies		0%		0%
4.	Advertising by 3rd parties		0%		0%
5.	Data commercialization		0%		0%
6.	EU Funding		0%		30%
			100%		100%

Expected profit margin	20%
Payment transaction fee	1,0%
Value Added Tax (VAT)	20%

Fig. 4.6 Examples of revenue sources data entry

level user experience, taking into account the diversity of passenger needs, offering personalized services and serving areas that are not economically covered today. Consequently, speaking about robomobility raises the question: is the use of autonomous vehicles economically, socially, and environmentally interesting?

Nonetheless the question of robomobility is still cemented in the triad Technology/Regulation/Uses. For instance, the KPMG (2015) study proposes the Autonomous Vehicles Readiness Index by assessing four key areas of preparedness for 20 nations: infrastructure, technology, regulatory, and user acceptance. No analysis was accorded to the economic impact of autonomous driving.

Public transport includes various services that provide shared mobility to the general public by means of buses, trains, ferries, subways, etc. and plays an important and unique role in the overall shaping of the urban public transport, by providing affordable and efficient basic mobility for urban travel.

Changes in itineraries and planning can have diverse impacts (benefits and costs) on the complete public transport ecosystem and can change the urban planning landscape. Therefore, any mobility project should include an in depth study of the economic impacts of the introduction of the new disruptive services or public transport; by analyzing benefits and costs not only from the point of view of service operation, but also quantify the indirect effects and the externalities like, parking cost savings, or efficient land development benefits, change of modal transfer, working hour gains, gains in waiting time, energy savings, carbon footprint, noise, air pollution, etc.

Since public transport is shaped by a complex ecosystem, the evaluation of the economic impact has to be done in a holistic way, taking into account not only direct costs but also quantify the indirect benefits, such as vehicle ownership, parking cost savings, or efficient land development benefits, resulting from the public service personalization as on-demand trips. The economic analysis of the used autonomous electric vehicles must examine business viability as well as economic impacts for users and cities.

EASI-AV covers the scope since it integrates internal cost-benefit analysis of the service including investment and operation costs as well as a cost-benefit analysis of the environmental impact of the service (externalities).

By offering a global economic comparison between an autonomous service and any other mobility mode, EASI-AV helps policy makers to decide, on the one hand, how and with which characteristics an autonomous transport service can be deployed and, on the other, what would be the effect of this deployment.

4.4.2 Scenarios Assessment

The economic impact evaluation must also help shape the future of mobility by proposing evaluated scenarios. Prospecting the future is a mandatory process for decision makers; scenarios represent the fuel for strategic investment decisions. Mobility models, and especially collective mobility models, are mostly built on proactive and transformative public strategies.

The design of scenarios aims at strengthening strategic thinking models of decision makers and reducing the negative effect of cognitive biases. Scenario for urban mobility is not simply a forecast of the most probable outcome, but rather it creates a set of plausible futures challenging the prevailing mind-set and status quo.

There are two kinds of scenarios: 1) international scenarios prospecting the future of mobility based on macro trends leveraged by global technology and society changes, and 2) local scenarios prospecting innovation propensity to success based on micro trends and leveraged by local initiatives. EASI-AV targets the latter type of scenarios by proposing scenarios viability evaluation.

Through economic impact evaluation, policy makers can test and evaluate different levels of personalized services, calculating costs and benefits for different stakeholders, such as public transport operators, collectivity, the leading organization, or passengers.

EASI-AV provides a framework to evaluate sustainability footprint of robomobility with value creation for different stakeholders (city, PTO, passengers, and any organization willing to introduce an autonomous mobility service). EASI-AV helps to calculate the viability of new business models. EASI-AV will not propose new concrete passenger use cases, but it gives the framework to evaluate the economic viability of the deployment of a specific mobility adapted to these cases and its global impact.

Furthermore, the tool will help to evaluate new service business models that will transform the "simple" ride into a user experience, taking into account the diversity of passenger needs, offering them with personalized services. A survey we conducted in 2019 (Mira-Bonnardel, 2021) on uses of autonomous vehicles by a local population allowed us to picture daily scenarios combining different options/services (Table 4.2).

Each time slot comes with its own business model with relevant partners, customers, or needs. Thereby, the overall organization, revenue model, communication channels, logistic and fleet management must be adapted.

EASI-AV ambitions to help valorize globally the economic side of any scenario combination and in doing that, helps decision-makers to choose with knowledge of economic impact.

Table 4.2 Examples of daily usage scenarios for AVCTs

Time slots	Options	Use cases
6 am – 9 am Predetermined journeys	R1S1	Transportation with predetermined stops for regular commuters, fixed time mobility (employees and schoolchildren)
9 am – 5 pm Journeys on request	R2S2	Transportation of goods (last mile) in city centers for retailers and individuals, with booking and connection to track the delivery process in real time
		Transportation for targeted needs (people with reduced mobility, leisure centers, care centers, specific goods, etc.)
		Transportation for disabled people at set times
		Transportation for city tours and outings
5 pm – 8 pm Predetermined journeys	R1S1	Transportation with predetermined stops for regular commuters, fixed time mobility (employees and schoolchildren)
8 pm – 6 am Journeys on request	R2S1	Night transportation for specific and emergency requests (like injured or sick people, delivery, deliveries for hospitals, tourist trips, etc.). Specific requests should be privately funded (individuals, travel agencies, retailer associations, etc.)

4.4.3 Current Limits of EASI-AV

EASI-AV is still a work in progress. The web application is under development and will likely be on open access by the end of 2022.

With public transport being a complex ecosystem, including not only transport operators, passengers, and policy makers but a lot of different stakeholders, such as software providers, mobility platforms, vehicle manufacturers, insurance companies, telecoms companies, infrastructure construction companies, maintenance companies, data provider companies. Each stakeholder may facilitate or hinder the deployment of autonomous collective transport. Therefore, they should be able to analyze scenarios for their own economic standpoint.

In that way EASI-AV is still limited, since it is designed as a decision-making tool for local authorities (a city government or a regional government), national policy makers, companies or universities needing to offer a mobility service on their campus. It is not designed for all stakeholders of the mobility ecosystem.

The other limitation of EASI-AV lies in the fact that it does not take into consideration the social impact of robomobility on unemployment. Sooner or later, regulation may no longer require any safety driver in the vehicles, but instead, remote supervisors to monitor a fleet of 5 to 10 vehicles. This change will automatically impact drivers' level of employment and local unemployment rates. Since Schumpeter's creative revolution, we know that this consequence will be only temporary until drivers get trained for other competencies. Yet this impact should be taken into account as a social effect (so should security against vandalism and other sources of violence, or other local social side effects). Our aim for the future is to expand EASI-AV in that direction.

4.5 Conclusion

The large-scale deployment of autonomous collective vehicles, combined with online services, user profiling, and dynamic itinerary optimization, will have a snowball disruption-effect on today's public transport model. The disappearance of drivers will allow transport operators to deploy more vehicles, leading to reducing the size of the vehicles, which, in its turn, will allow vehicles to divert from the predefined itineraries and start offering on-demand door-to-door services (based on online dynamic reservations and optimization), and transforming public transport into transit service personalization.

This transformation will require a high level of investment. Anticipating the economic impact of investments is a usual task for any decision-maker or investors. Surprisingly, this seems not to be the case for autonomous mobility investment, at least very few elements have been published on this topic. Within the European AVENUE project, we have worked with transport operators and local cities' governments to build a tool enabling the economic calculation for the implementation of autonomous vehicles into their transport network and the valorization of deployment scenarios. This tool: EASI-AV, was successfully tested on the experimentation site in Luxembourg City and proved to be a real support tool for decision-making in mobility strategy.

Further analysis and programming work need to be conducted before it allows to valorize the global socio-economic impact of robomobility. The authors work on it and the web-app should be posted open access online by the end of 2022.

Acknowledgments The project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 769033.

References

Ainsalu, J., et al. (2018). State of the art of automated buses. *Sustainability, 10*(3118), 2–34.

Antonialli, F. (2021). Autonomous shuttles for collective transport: a wordwide benchmark. *International Journal of Automotive Technology and Management, 21*(1/2), 5–28.

ARK Invest. (2017). Mobility-as-a-service: Why self-driving cars could change everything. Available online: www.research.ark-invest.com/hubfs/1_Download_Files_ARK-Invest/White_Papers/Self-Driving-Cars_ARK-Invest-WP.pdf. Accessed 14 Apr 2020.

Attias, D. (2017). The automobile world in a state of change: from the automobile to the concept of auto-mobility. In D. Attias (Ed.), *The automobile revolution: Towards a new electro-mobility paradigm* (1st ed.). Gewerbestrasse, Switzerland: Springer.

AVENUE. (2018). *Objectives of the avenue project*. Available online: Retrieved on. www.h2020-avenue.eu/content/objectives-avenue-project. Accessed 14 Apr 2020.

Bansal, P., & Kockelman, K. M. (2017). Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies. *Transportation Research Part A: Policy & Practice, 95*, 49–63.

Bösch, P. M., Becker, F., Becker, H., & Axuausen, K. W. (2018). Cost-based analysis of autonomous mobility services. *Transport Policy, 64*, 76–91.

Bulteau, J. (2016). Revisiting the bottleneck congestion model by considering environmental costs and a modal policy. *International Journal of Sustainable Transportation, 10*(3), 180–192.

Catapult Transport Systems. (2017). Market forecast for connected and autonomous vehicles. Available online: www.assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642813/15780_TSC_Market_Forecast_for_CAV_Report_FINAL.pdf. Accessed 13 Apr 2020.

Clausen, C. (2017). Niche management of Autonomous Vehicles for positive environmental outcomes in Copenhagen: Evaluating the feasibility of purposive measures through scenario analysis. Master's thesis, Lund University, Lund, Sweden.

European Commission (2019). Handbook on the external costs of transport. Available online: https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1. Accessed 10 May 2021.

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy & Practice, 7*, 167–181.

Gandia, R. M., Antonialli, F., Cavazza, B. H., Neto, A. M., Lima, D. A. D., Sugano, J. Y., Nicolaï, I., & Zambalde, A. L. (2018). Autonomous vehicles: scientometric and bibliometric review. *Transport Reviews, 38*, 1–20.

Harris, R. (2018). *Shuttle diplomacy: The path to deployment*.. Available online: www.publishing.ninja/V4/page/4572/245/270/1. Accessed 14 Apr 2020.

Henderson, H., Veder, A., Li, L., Johnson, M. (2017). Feasibility of electric autonomous vehicles on Ohio State University Campus. Available online: www.kb.osu.edu/bitstream/handle/1811/81632/1/ENRAEDE4567_ElectricAutonomousVehicles_au2017.pdf. Accessed 14 Apr 2020.

Kalakuntla, S. P. (2017). *Adopting autonomous bus to a transit agency: a cost-benefit analysis*. Available online: www.academia.edu/34636124/ADOPTING_AUTONOMOUS_BUS_TO_A_TRANSIT_AGENCY_A_COST-BENEFIT_ANALYSIS. Accessed 14 Apr 2020.

KPMG. (2015).Connected and Autonomous Vehicle –The UK Economic Opportunity. Available online: www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UK-Economic-Opportu...1.pdf. Accessed 13 Apr 2020.

Litman, T. (2018). Autonomous vehicle implementation predictions. *Implications for Transport Planning*. 2018. Available online: www.vtpi.org. Accessed 13 Apr 2020

Lo, A. (2021). Luxembourg makes all public transport free. Available online: https://edition.cnn.com/travel/article/luxembourg-free-public-transport/index.html. Accessed 10 May 2021.

Merat, N., Madigan, R., & Nordhoff, S. (2017). Human factors, user requirements, and user acceptance of ride-sharing in automated vehicles. Available online: www.google.com.br/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=2ahUKEwi97onnuPXhAhWjAmMBHV0vANoQFjABegQIBBAC&url=https%3A%2F%2Fwww.itf-oecd.org%2Ffile%2F16355%2Fdownload%3Ftoken%3DwzML3Ngi&usg=AOvVaw3u20zlsLVA-aIGHQmK0810. Accessed 14 Apr 2020.

Mira-Bonnardel, S. (2021). Robomobility for collective transport: a prospective user centric view. *International Journal of Automotive Technology and Management, 21*(1/2), 99–120.

Mira-Bonnardel, S., & Attias, D. (2018). The autonomous vehicle for urban collective transport: Disrupting business models embedded in the smart city revolution. In *Proceedings of International Colloquium of Gerpisa: Who drives the change?* New and traditional players in the global automotive sector. São Paulo, 26.

Mira-Bonnardel, S., & Attias, D. (2019). Autonomous vehicle for flexible public transportation systems: towards a shared on demand mobility. In *Proceedings of International Colloquium of Gerpisa:Paradigm Shift?* The automotive industry in transition. Paris, 27.

Ongel, A., Loewer, E., Roemer, F., Sethuraman, G., Chang, F., & Lienkamp, M. (2019). Economic assessment of autonomous electric microtransit vehicles. *Sustainability, 11*(648), 1–18.

Rethink (2017). Disruption, implications and choices rethinking transportation 2020–2030 the disruption of transportation and the collapse of the internal-combustion vehicle and oil industries.

Available online: www.static1.squarespace.com/static/585c3439be65942f022bbf9b/t/591a2e4be6f2e1c13df930c5/1494888038959/RethinkX+Report_051517.pdf. Accessed 14 Apr 2020.

SAE. (2016). Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles J3016_201609. Available online: www.sae.org/standards/content/j3016_201609/. Accessed 14 Apr 2020.

Zhang, W., Jenelius, E., Badia, H. (2019). Efficiency of semi-autonomous and fully autonomous bus services in trunk-and-branches networks. *Journal of Advanced Transportation*, 1–18.

Chapter 5
From Demonstrator to Public Service: The AVENUE Experience

Dimitri Konstantas

Abstract The AVENUE projet's vision for future public transport in urban and suburban areas is that autonomous vehicles will ensure safe, rapid, economic, sustainable, and personalised transport of passengers, while minimising vehicle changes and maximising vehicle utilisation. The goal of the project is to provide door to door, on-demand autonomous public transport services allowing commuters to benefit from the full capabilities of autonomous busses.

However, the road to a public transportation service is not so simple. Legal and regulatory requirements create barriers and obstacles, raising the costs and delaying the deployment of the services. In spite of the efforts from the European Commission for a harmonisation of the homologation process, urban public transportation is under national and local legislation, creating a highly fragmented European environment. In this chapter, we present some of our experience in setting up and deploying Autonomous busses in two cities, Geneva and Copenhagen.

Keywords Autonomous busses · Public transport · On-demand transport · Homologation process · European Commission Horizon 2020

5.1 Introduction

During the last few years, the use of autonomous vehicles for public transportation has been gaining interest from all actors in public transportation services. This is due to the potential of autonomous vehicles to reduce transportation costs, provide greener solutions for suburban areas, and improve the quality of public

D. Konstantas (✉)
University of Geneva, Geneva, Switzerland
e-mail: dimitri.konstantas@unige.ch

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_5

transportation services. The autonomous vehicle based services provide a promising solution in suburban areas, where conventional public transportation services are not viable due to, for example, low number of passengers, or in urban areas, where personalised public transportation services are demanded by the passengers.

In this direction, companies are proposing new technologies for autonomous driving (Bestmile, 2020; Chen et al., 2020; de Veronese et al., 2020), cities are testing and exploring the autonomous driving possibilities (Iclodean, Cordos, & Varga, 2020) in experimental sites, while the EU is funding innovation projects to study and boost the deployment of autonomous vehicles in public transportation (Horizon 2020).

The vast majority of the initiatives target the development and improvement of the related technologies, which are tested under experimental setups of trials and demonstrators, in closed or open roads, and under controlled conditions of operation. The most important example being the Google Wyamo project (Schwal, Daniel, Victor, Favarò, & Hohnhold, 2020), where data from thousands of driving hours and kilometres are collected and analysed, contributing to the improvement of the autonomous capabilities and safety of the vehicles.

However, there is a major difference between the large scale tests performed in the United States and Europe. In the United States, the primary target is the development of "private" autonomous vehicles, in an environment offering large spaces and roads. In contrast, in Europe, the main target is to boost shared public transportation, in dense urban environments, with narrow roads and restrained space. Although the underlying technologies seem to be much the same in both cases, there is a great difference in the roadmap for the large scale deployment in terms of target services.

Offering shared "car taxi" services is not the same as offering public transportation services. The passenger needs and expectations, the service areas, the legal framework, the business models, and even the required technologies are radically different in each case. In the AVENUE[1] project, where we target the large scale deployment of autonomous vehicles for public transportation, after 30 months of services' deployment, we have witnessed the barriers and obstacles from passing from an experimental trial to a full "commercial" service. Our experience shows that today, in Europe, on the one hand, the regulatory framework does not facilitate, and in many cases simply does not allow, the full exploitation of autonomous vehicle capabilities for public transportation, while on the other, the public transportation services' quality, to which the European citizens are used, is not easy to achieve with the existing technological state of art, requiring new innovative services that will offer the passengers the same quality level as the traditional transportation services.

In the chapter, we present an overview of the issues identified for the deployment of autonomous mini-busses toward offering a service that can proudly bear the title of "public transportation service". We present the two most characteristic cases of

[1] This project has received funding from the European Union's Horizon, 2020 research and innovation program under grant agreement No. 769033.

the project, the Geneva deployment and the Copenhagen deployment efforts and status.

5.2 Overview of the AVENUE Project

AVENUE aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of autonomous minibuses in low to medium demand areas in four European demonstrator cities (Geneva, Lyon, Copenhagen and Luxembourg) and two replicator sites (Sion and Esch-sur-Alzette). The AVENUE vision for future public transport in urban and suburban areas is that autonomous vehicles will ensure safe, rapid, economic, sustainable, and personalised transport of passengers. AVENUE introduces disruptive public transportation paradigms on the basis of on-demand, door-to-door services, aiming to set up a new model of public transportation, by revisiting the offered public transportation services and aiming to suppress pre scheduled fixed bus itineraries.

Vehicle and transport services that substantially enhance the passenger experience as well as the overall quality and value of the transport service are designed and tested, adapted also for with special needs passengers, like elderly people, people with disabilities, and vulnerable users. Road behaviour, security of the autonomous vehicles and passengers' safety are central points of the AVENUE project.

At the end of the AVENUE project, the mission is to have demonstrated that autonomous vehicles will become the future solution for public transport. The AVENUE project will demonstrate the economic, environmental, and social potential of autonomous vehicles for both companies and public commuters while assessing the vehicle road behaviour safety.

5.2.1 On-demand Mobility

Public transportation is a key element of a region's economic development and the quality of life of its citizens. Governments around the world are defining strategies for the development of efficient public transportation based on different criteria of importance to their regions, such as topography, citizens' needs, social and economic barriers, environmental concerns, and historical development. However, new technologies, new modes of transport and services are appearing, which seem to offer very promising solutions to the support of regional strategies for the development of public transport.

On-demand, door-to-door mobility services are today provided by taxi services, being (in the vast majority) individual transport services, with a high cost. Several cities (Pettersson, 2019) have introduced on-demand door-to-door services for public transportation for areas where the demand for transport is diffuse and regular transport is inefficient. On-demand public transport differs from other public transport services in that the vehicle does not follow a fixed route and does not use a predefined timetable. Unlike taxis, on-demand public transport is also not individual. An operator or an automated system takes care of the booking, planning, and organisation, with reservations required to be made minutes to hours before the requested trip time.

In the AVENUE project, we are convinced that the use and integration of autonomous vehicles for on-demand door-to-door services, with live and dynamic routing and reservations, has the potential to significantly improve services and provide solutions to many of the problems encountered today in the development of sustainable and efficient public transport. The creation of these types of services is the core target of the AVENUE project.

5.2.2 Autonomous Vehicles

A self-driving car, referred to in the AVENUE project as an Autonomous Vehicle (AV), is a vehicle that is capable of sensing its environment and moving safely with no human input, to reach a specific destination following a path that it defines on its own. The choice of Autonomous vs. Automated was made in AVENUE since in the current literature, *Automated vehicles (*and *automated driving)* refers to a vehicle which has a technology dedicated to assist the driver, and where some driving tasks can be transferred to the vehicle computer system. A notable example are the Tesla vehicles (TESLA, 2021) which provide maximum assistance to the driver, but cannot operate without a driver ensuring constant vehicle control. *Autonomous vehicles*, on the other hand, are fully automated vehicles equipped with the required technologies capable of performing not only all driving functions, like identifying and bypassing obstacles, changing lane, accelerating and braking based on road conditions (red-lights, traffic jams, etc.) but also capable of choosing and modifying the route and destination, the time to operate a trip, the places to stop and pick up passengers without any direct human intervention. Although the driving and road behaviour functions are integrated in the vehicle, this is not enough, according to the strict interpretation of the term, to name these vehicles *autonomous*, but rather *automated*. Autonomicity implies the ability to decide the trip to take, the destination to reach, the places to stop, etc. This part can only be achieved with systems that are able to analyse the passenger needs and "orchestrate" the fleet of vehicles (Fig. 5.1).

This latter is the target of the AVENUE project: to develop an integrated system comprising automated vehicles and services that independently select and optimise the vehicle destination and routes, based on passenger demands, creating thus what we can call an "autonomous vehicles' public transportation service".

In relation to the SAE levels (SAE, 2018), the AVENUE project will operate SAE Level 4 vehicles, that is, operating in a predefined mapped area (which is always the case for public transportation services!), and with vehicles that do not have driving wheel and pedals, and which are receiving destination instructions from a remote system (what we call the "fleet orchestration" (Bestmile, 2020).

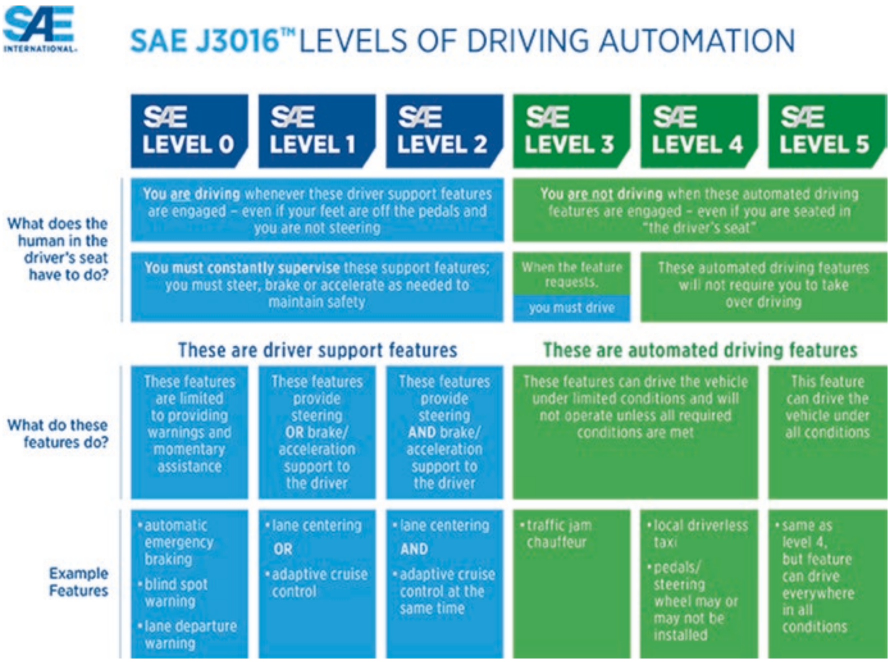


Fig. 5.1 SAE classification of the Automation levels. (©2020 SAE International)

5.2.3 The AVENUE Autonomous Vehicles

In AVENUE, we are using the NAVYA *Autonom Shuttle* (NAVYA, 2021), which has a capacity of 14 persons, and is authorised, in the AVENUE sites, to operate at a maximum speed of 25–30 km/h.

In the most advanced site of the project, at Belle-Idee, Geneva, the provided service implements a fully autonomous public transportation, in an open street environment.

The vehicles are capable of recognising obstacles (and identifying some of them), identifying moving and stationary objects, and autonomously deciding to bypass them or wait behind them, based on the defined policies. For example, with small changes in its route, the AVENUE shuttle is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE vehicles are able to handle different complex road situations, like entering and exiting round-about in the presence of other fast running cars, stopping at zebra crossings, and communicating with infrastructure via V2I interfaces[1] (ex. red light control) (Figs. 5.2 and 5.3).

[1] This feature is tested by Keolis Lyon at the site of the Groupama Stadium, Lyon.

Fig. 5.2 The NAVYA Autonom Shuttle

Fig. 5.3 Inside the NAVYA Autonom Shuttle

The shuttles used in the AVENUE project technically can achieve speeds of more than 60 km/h. However, this speed cannot be used in the project demonstrators for several reasons, ranging from regulatory to safety. Under current regulations, the maximum authorised speed of an autonomous vehicle is 25 or 30 Km/h (depending on the country and site). In the current demonstrators, the speed does not exceed 25 km/h. Another, more important reason for limiting the vehicle speed is safety for passengers and pedestrians. Due to the fact that the current LIDAR has a range of 100m and the obstacle identification is done for objects no further than 40 meters, and considering that the vehicle must safely stop in case of an obstacle on the road (which will be "seen" at less than 40 meters distance) we cannot guarantee a safe braking if the speed is more than 25 Km/h. Note that technically the vehicle can make a harsh brake and stop within 40 meters in high speeds (40 -50 Km/h), but then the brake would be too harsh, putting in risk the vehicle's passengers. The project is working to find an optimal point between passenger and pedestrian safety, while a new generation of LIDARs extends the usable object identification distance to 80m (not available, however, for the AVENUE vehicles).

5.2.4 Autonomous Vehicle Service Operation Overview

We distinguish in AVENUE three levels of control: *micro-navigation*, *macro-navigation*, and *fleet orchestration*. *Micro navigation* is fully integrated in the vehicle and implements the road behaviour of the vehicle; micro-navigation will provide the required obstacle recognition and bypassing, lane changing (when authorised), turning points, speed control, etc.

The next lever of control is the *macro-navigation*, where the destination is defined and the path to follow. This is the same function as the widely used GPS navigators that provide to the driver of the individual vehicle instructions of the road to take, but are not interfering with the on-road driver decisions.

In the operation of a public transportation service, we will have a large number of vehicles operating within the designated service area. Which vehicle will serve which trip request is done by the *fleet orchestration* system, which manages (among others) the choice of the specific vehicle that will be used in reply to a specific passenger trip request.

For the Micro-navigation, the Autonomous Vehicle combines a variety of sensors to perceive its surroundings, such as 3D video, LIDAR, sonar, GNSS, odometer, and other types of sensors. Control software and systems, integrated in the vehicle, fusion and interpret the sensor information to identify the current position of the vehicle, detecting and classifying obstacles and objects in the surrounding environment, and choose the most appropriate reaction of the vehicle, ranging from stopping to bypassing the obstacle, reducing its speed, making a turn, etc.

For the Macro-navigation, that is the destination to reach and the possible routes to follow, the functionalities are present to both the vehicle and the vehicle management system (at the back-office), The Navya vehicles have an integrated navigator, which is used when the safety operator defines a destination to reach. In this case, the vehicle decides the best route to follow for reaching the destination. However, the vehicle management system also provides the same functionalities, and, being a back-office service, can also integrate other related information, like blocked roads, traffic jams, and identify a better route for reaching the destination. In AVENUE, the mission definition (the destination to reach) is sent to the vehicle via a dedicated 4G communication channel. This mode of operation we call *Mission Management* mode and does not require any intervention by the vehicle safety operator.

The Fleet Orchestration system, (that eventually will be installed at the premises of the public transportation operator), takes into account all available vehicles in the service area, their status (like battery level, passenger service capabilities, number of passengers in the vehicle, etc.), the passenger requests and needs, the operator policies, the street conditions (ex. closed streets), etc. and selects the best suited vehicle to serve a trip request, sending route, and stop information to the vehicle (route to follow and destination to reach).

The complete planning is dynamically adapted depending on new trip requests, changing street/weather conditions, changes in the vehicle status and operator policies to respect.

5.3 From Demonstrator to Public Service

During the last five years, we have witnessed numerous deployments of Autonomous shuttles around the world (Iclodean et al., 2020), where public authorities, municipalities, transport operators are commissioning 1 to 2 AVs and offer a basic service with a manually operated AV. That is, the safety operator defines the destination bus-stop using the on-board vehicle panel, in a predefined itinerary, usually a line or a circle, and the vehicle drives autonomously to it. This type of simple demonstration service can be technically deployed within 48 hours, requiring a mapping of the street, the definition of the path and its configuration, and the installation of some basic infrastructure (a GNSS antenna). However in deploying this type of small scale demonstration service, the prospective service operator will face a first obstacle: the acquisition of the required (legal and regulatory) authorisations for the use of the public street and the homologation of the vehicle. These authorisations can take weeks or months (or even years!) to be granted, and can require large investments in effort and costs. We have seen many times that city officials interested to test or demonstrate autonomous vehicles in their sites, are not aware of regarding the underlying regulatory requirements and the delays they might induce for the deployment.

If we now want to go further, as is the case in AVENUE, and target the deployment of a "public transportation" commercial service, the legal and regulatory requirements become even more complicated (and also drastically different in every EU country!). The road to the deployment of autonomous vehicles for public transportation is filled with obstacles and barriers. On the one hand, the technology still needs to improve and provide solutions to the many issues related to autonomous driving in complex road situations, while on the other, the regulatory restrictions, from one side, do not allow the full exploitation of autonomous vehicle capabilities on the road, while from the other, can become very costly.

5.3.1 Regulatory Framework

When we talk about Autonomous Vehicles for Public Transportation, we automatically fall into two distinct regulatory frameworks: first on the autonomous vehicles and their certification for using the public roads, and second on the public transportation certification of transport routes and the required passenger services and facilities. On the first framework, the European Union has achieved some level of harmonisation, while the second remains largely under national and local legislation.

5.3.1.1 Autonomous Vehicles' Certification

The first regulatory obstacle in driverless mobility is that, according to *the letter of the law*, driverless mobility is illegal in all European countries. All national legislations on vehicles are based on the Vienna convention (Vienna Convention, 1968) where it is stipulated (article 8) that each moving vehicle must have a driver. In the 2014 revision of the Vienna Convention on Road Traffic, automatic systems are considered legal, as assisting the driver who should be able to turn them off at any time or take control of the system at any time.

Although legislation on authorising fully autonomous driving is enabled in a few states in the USA (HG, 2021) and some European countries have voted laws anticipating fully autonomous driving, authorisations are only given for experimental trials (Autovista Group, 2019). The European Parliament adopted in January 2015 the *Draft Report on Autonomous Driving in European Transport* (van de Camp, Kohn, & Radev, 2018), setting the framework for a Europe-wide legislation and opening the road for member countries to adopt the relevant laws.

In April 2019, the European Commission *Technical Committee – Motor vehicles (TCMV),* in order to harmonise the exemption procedure for EU approval of automated vehicles, published, the *Guidelines on the exemption procedure for the EU approval of automated vehicles* (European Commission, 2019)*,* which *provide rules for EU countries to follow in their ad-hoc safety assessments.* However these guidelines *focus on <u>automated vehicles</u> that can drive themselves in a limited number of driving situations … on levels 3 and 4 of the Society of Automotive Engineers International (SAE)*, defining the rules for how the driver can take over the vehicle control. As such, they do not address the case of fully autonomous vehicles.

Based on the above, it has become simpler to validate a vehicle that has already been validated in a European country, in a second country, after passing some basic tests (like a breaking test).

However, a second obstacle for putting autonomous vehicles on the road in Europe comes from the 2018 revision of the EU Directive 2007/46/EC (which came in force on 1 September 2020), which regulates the design and operation of new vehicles, stipulating that only mass-produced cars can be used on public roads, which must be type-approved, in compliance with the technical requirements and administrative procedures defined by the Directive. However, the creation of a mass-production chain for autonomous vehicles and the certification of the production chain requires a high demand of vehicles in the market, which today is not the case for the public transportation autonomous shuttles. As a consequence, the lack of production chains results in each autonomous shuttle needing to be individually certified. However, once certified in a European country, it can be imported to another country, (the individual vehicle, and not a same model vehicle!) and be very fast validated for operation (in theory, within 24 hours).

However, fully autonomous driving will only be legalised (with a revision of the Vienna Convention on Road Traffic) once the technical developments are thoroughly tested and validated. For this, the autonomous vehicle manufacturers must prove the safety of the technology under real road conditions, having accumulated sufficient numbers of driving hours and proven the safe reaction of the vehicles under diverse conditions. Waymo in the USA, after having collected hundreds of thousands of driving hours, is still not able to fully guarantee the safe behaviour of the vehicles. In Europe, the shuttle manufacturers (NAVYA, EasyMile, and others), with budgets to a fraction of what is invested in the USA, will have difficulties to demonstrate road safety to the extent that the law might require.

5.3.1.2 Autonomous Vehicles for Public Transportation

Under article 14 of *The Treaty on the Functioning of the European Union* and Protocol 16 of the same Treaty, urban public transportation is left as competency to the local public authorities. The PSO Regulation (Regulation 1370/2007) *on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos 1191/69 and 1107/70* (EUR-Lex, 2007), leaves *a wide discretion to competent transport authorities in providing, organising and commissioning essential urban public transport services* (UITP, 2021). As a result, the European urban public transportation is largely fragmented, with specific laws and regulations applied to different levels (city, cantonal, national) and with a multitude of public bodies to take the decisions and give the required approvals.

The related regulatory authorities are asked to provide an authorisation for the road segments where vehicles can operate and validate the public transportation routes. Under the existing laws in all EU countries, regular public transportation is based on fixed/predefined routes and itineraries, bus stops, and time-tables. The related regulations are based on this model for the validation of any new public transportation service and routes. However, on-demand, door-to-door public transportation, where there are no predefined itineraries, nor time-tables, is not part of the existing regulatory framework. This results in route homologations being made on a case-per-case basis, for a specific site, and only as a test site for new technology vehicles. Each site needs to be validated individually, and any change, no matter how minor it may be, might require restarting the process (which can be very costly and time consuming, taking from months to years).

Urban Public transportation, as offered by the accredited operators, is also bound to provide services and accessibility to special needs passengers, and offer some basic infrastructure and amenities for the passengers. Regular, time-based public transportation requires, for example, bus stop installations (shelters, zig-zag lines on the road), allow access to special needs persons (wheel-chair access, braille signs for blind persons, etc.). These amenities are regulated and obligatory for a *public transportation* line, and are required for the validation of the bus line and road as a *public transportation*. However, with on-demand, door-to-door vehicles, the notion of a bus stop disappears, since the autonomous vehicle can stop (almost) anywhere, and it is inconceivable to instal bus stops everywhere!! As a result, the creation of autonomous vehicle-based public transportation requires a change of view and innovative solutions under the current legal frameworks.

5.3.2 Passenger Services

In traditional, driver-based public transportation, a driver is always present in the bus. Although the common idea of the driver is that he “drives the vehicle”, in reality a driver provides numerous services, formal or informal, for the passengers and the care of the vehicle. Passengers can ask questions to the driver about itineraries, ticketing issues and even ask to be informed, for example, to go out at a specific stop (especially for persons with special needs). The driver will also help wheelchair passengers to enter the vehicle, guide elderly and visually impaired for a safe trip, and of course intervene in case of an accident, incivilities in the bus, or vandalism, providing thus a sense of safety to the passengers. The driver also controls the status of the vehicle, and decides to bring it for maintenance or cleaning, in coordination with the operator services.

All these services provided by the driver contribute to the service quality of the public transportation, improving the safety, well-being and passenger satisfaction. The suppression of the driver in an autonomous public transportation service, and the need to maintain the same level of transport service quality, means that new innovative services must be introduced, using either electronic means or by encouraging social mutual assistance, when possible. However, the introduction of new services might have important implications for the vehicle design and required new infrastructure that needs to be installed by the public transport service operator. Furthermore, due to the novelty of the driverless operation of public transportation buses, one should not underestimate the psychological effects that an autonomous vehicle can have to parts of the population. For example, what will be the reaction of an elderly person that is used to a fixed itinerary, when the shuttle will, each time, change its itinerary based on the trip requests of the moment? It might generate anxiety (*am I in the wrong bus?*) or even fear, reducing the acceptance of the service, since there is no driver to provide an explanation and reassure the passenger (we clearly understand, however, that this issue is a transient problem, which will disappear when the current young generations that will grow up with these types of services will reach an advanced age). In addition, the automatisation of the surveillance of passengers (for identification of aggressions, vandalism, etc.) raises many questions regarding privacy and data protection that needs to be addressed and regulated before the services can be deployed.

It is clear that the introduction of autonomous, on-demand, door-to-door transport services will be based on advanced and sophisticated systems allowing passengers to dynamically reserve a trip, in just a few minutes before the desired departure, to maybe a few hours in advance, in a simple and intuitive way. This simplicity of reservation, combined with the existing monthly and yearly unlimited travel tickets, might encourage passengers to start using the service for trips for which the use of public transport today is unimaginable. For example, for going a 100m distance (to the bakery), today no-one would imagine taking a bus or a taxi, since either the distance to the bus stop is much further away or the price of the taxi is too high. However, with the on-demand door-to-door service, which will be free of charge and simple to order, citizens will be tempted to call an autonomous service for a 100m trip. This change of behaviour will have a major impact in the organisation of the service, introducing thousands more of travel kilometres that do not exist today. The question of the operators is thus if they must introduce measures to discourage this type of behaviour, and if yes how to implement them and whether they will be acceptable by the citizens.

5.4 The AVENUE Experience in Organising Autonomous Vehicles' Public Transportation Services

At the end of the 30th month of the AVENUE project (fall 2020), AVENUE operated regular public transportation services at five sites, namely, in Geneva operated by the TPG in Meyrin city, site in Lyon at the Groupama Stadium operated by Keolis-Lyon, in Luxembourg, at the Pfaffenthal site, operated by Sales-Lentz, and at Oslo at Ormøya, operated by Amobility (under the trademark Holo), and at Nordhaven, Copenhagen by Amobility. A new site is under testing in Geneva, at the Belle-Idee hospital area, where the full power of autonomous vehicles, with on-demand, (quasi) door-to-door services, under mission management mode is deployed.

Setting the sites and obtaining the required authorisations, was not always a simple task. In this section, we present an overview of the barriers and obstacles faced and present some of the solutions given to bypass them, from two of the demonstrators, Geneva and Copenhagen, that represent somehow the best and worst case scenarios. The Geneva demonstrator setup, followed a steady and predictable path in obtaining the authorisations in a relatively short time and the Copenhagen where it took more than three years to obtain the authorisations, only to be abandoned finally due to the complexity of the procedures and the (too?) strict conditions for a simple fixed route service (making the deployment of an on-demand service quasi impossible within the time frame of the project).

5.4.1 The Geneva Demonstrator

Swiss authorities are having a positive attitude towards the development of future transport modes and fully support initiatives, such as autonomous driving and connected vehicles. In order to run a Pilot project, which falls out of the scope of current existing Swiss legislations, a predefined process had to be followed in order to be able to acquire the necessary permissions.

Switzerland, officially the Swiss Confederation, is a federation of 26 cantons. Swiss cantons have an independent government and are an administrative subdivision of the Swiss Confederation. Municipalities are the lowest level of administrative division in Switzerland. Each municipality is part of one of the Swiss cantons, which form the Swiss Confederation. In order to receive an accreditation for a public transportation service with "autonomous" shuttles, nine Authorities have to approve the pilot project, providing approvals for the vehicles and proposed routes. The relevant authorities are (Table 5.1):

Table 5.1 Swiss authorities and responsibilities

Authority	Acronyms	Level	Responsibility
General Secretariat of Federal Department of the Environment, Transport, Energy and Communications	GS DETEC	Federal	Telecommunications
Federal Roads Office	FEDRO	Federal	Route
Federal Office of Transport	FOT	Federal	Vehicle, Passenger transport
Federal Office of Communications	OFCOM	Federal	Route
The Department of Infrastructure	DI	Cantonal	Route
General Transport Directorate of the Canton of Geneva	OCT	Cantonal	Route
Department of Security and Economy – Traffic Police	DSES	Cantonal	Route
Cantonal Vehicle Service	SAN	Cantonal	Route
Village/Town/City		Municipal	Route

5.4.1.1 Vehicle Homologation

The vehicle itself only needs to be homologated at a Federal level by the Swiss Federal Office of Transport. It concerns a technical approval of the construction and functioning of every single vehicle as supplied by the constructor and includes some security tests as well as a brake test and an in-depth check of the safety measures around the electric components. In Switzerland, the brake and electrical components tests are carried-out by a specialised firm. As mentioned above, every AV vehicle (and in Geneva we have four AV vehicles) requires its own homologation and testing, due to lack of a chain production.

Since an autonomous vehicle has the right to only drive on a predefined route, this specific route has to be defined and homologated before a formal authorisation to use the vehicle can be given.

5.4.1.2 Test Site Homologation

In order to homologate the test site, an applicant has to extensively describe the test site and also comply with standard concessions. The homologation process will take from three to nine months depending on the level of difficulty of the test site and the former experience with autonomous vehicle projects by the operator. The test site homologation for an autonomous vehicle includes the awarding of related concessions, in line with the process as followed for a non-autonomous vehicle.

A *telecommunications concession*, necessary for transmission of radio and 3/4/5 G signals, is delivered through the Federal Office of Communications (OFCOM) in Bern. Delivery of a concession takes up to around two months.

The *passenger transport concession*, necessary for the transport of people, is delivered through the Federal Transport Office (FOT) in Bern. Delivery of a concession takes up to around three months.

5.4.1.3 Application Process

The complete application process requires the assembly of several documents, counting to hundreds of pages, which must be provided to the different authorities. Table 5.2, provides a summary of the chapters and content of the application.

Several issues, however, arose during the homologation process. A first issue concerned the obligation for the site validation to provide fixed bus stops. Although

Table 5.2 Chapters and content for an application in Switzerland

Chapter	Information
Project	Description Official waiver request Objectives
Authorities	Operator service agreement
Concessions	Radio communication Transport of passengers
Routes	In-depth description
Bus stops	Description Identification
Vehicle	Description of the vehicle Transport capacity Detailed documentation
Safety	Operational safety measures Legal bases Derogation of traffic rules Compensation measures for the derogations of traffic rules
Operations	Concept Principals Timetable Remote supervision Documentation and procedures
Positions	Expert Trainer Super operator Operator
Operators	Operator commitment Operator instructions Accident procedures
Training	Theoretical training Practical training Trainers training Assessment, Certification
IT	Data security Software Embedded systems
Reporting	Authorities
Communication	Internal External Clients

Fig. 5.4 The Geneva TPG Belle-Idee site

the law requires the clear definition of fixed bus stops, the number of stops is left to the discretion of the operator. Based on this, we defined a large number of bus stops (70) and on-demand stop (the bus is not obliged to stop at all bus stops, but only to the ones requested by the passenger), this way creating a quasi-door-to-door service (actually a stop-to-stop service with a dense network of stops), since in any case a bus cannot simply stop anywhere (e.g., on a pedestrian crossing, in front of fire hydrant). At the same time, in order to fulfil the legal requirement for a fixed route, but maintain the on-demand routing, we defined a large number of fixed routes with several alternative, overlapping fix routes, from which the shuttle will choose the most convenient for the specific on-demand trip. Figure 5.4 shows the Bell-Idee site with the different routes (numbers and red route colour) and the bus-stops, (blue and green points).

Here we must mention that the Swiss authorities dispensed us from installing the obligatory bus stop infrastructure (shelter, zig-zag lines) to the numerous bus stops defined in the site.

A second issue we faced, but for which we have not yet a simple solution, is the obligation to provide access to wheelchair passengers. Public transport companies have the duty to offer transport for everyone, including the disabled. The Navya Autonom Shuttle is equipped with a manual folding ramp which can be deployed by the safety operator to give access to a wheelchair and can be retrofitted with an automatic ramp.

However Swiss legislation regarding the maximum slope for hand-propelled wheelchair ramps defines a:

- 18% grade when help is assured
- 6% grade when autonomous

In view of the height of the shuttle, and for driverless service (6% slope) a ramp with a length of more than three meters (sic!) would have been required. Clearly this is not possible. Alternative solutions are under study and will be evaluated during the full scale operation of the service in 2021.

5.4.2 The Copenhagen Demonstrator

The target of Amobility for Copenhagen is to have developed and implemented the autonomous mobility cloud in the Nordhavn district, in an on-demand (door2door) autonomous transport system without fixed routes, and with the whole zone mapped & geofenced. In Denmark, while the Danish authorities were being positive towards the development and implementation of future transport modes, including autonomous vehicles, the approval process of AVs falls under the regular legislative framework, making it very extensive and requiring a large number of documentation regarding the route, vehicle, safety, risk, and so forth.

The approval process for each project testing autonomous vehicles in Denmark is as follows:

- The Autonomous Vehicle has to be approved by the Danish Road Safety Agency
- An impartial third party, called *an assessor* (appointed by Danish law), has to approve the overall project.
- The application + assessor approval then has to be processed and commented on by a public Task force, consisting of the Danish Road Safety Agency, Danish Road Directorate, Director of Public Prosecutions and the Danish police.
- A legal declaration is then made and sent into hearing for all interested parties
- The declaration has to be approved by the Danish Transport Committee (elected politicians)
- Finally, the Minister of Transport has to approve the declaration and process.

The Ministry of Justice will, at some point during the process, be involved, as well as a three-week public hearing will be held.

The process is very long, with documents and clarifications requested at any stage, and if any change occurs, even the most minor, the process should almost start from the beginning.

5.4.2.1 The Role of the Assessor

One of the particularities of the Danish law in the approval process is that it requires that the application to the Danish Road Directorate include an assessment of the pilot project by a third party, called an “assessor”. The third party is typically an engineering company, which is paid to do their objective assessment. The company applying for approval of the autonomous project is paying the assessor, in this case, AMobility. The assessor shall, through different parameters, assess that the project can be done within normal road safety risks for that particular type of transport. There are no further detailed guidelines on how to assess this risk for autonomous vehicles.

The great challenge has been that the law states that the assessor holds the responsibility for assessing traffic risks in the autonomous pilot project. And with no detailed guidelines, a great deal of time had to been spent on agreeing with the assessor and the authorities when enough is enough, in regards to the documentation and descriptions that had to be handed in.

There has long been a tradition in Denmark for using assessors in rail projects. Since there were no clear guidelines provided for the new autonomous pilot projects, the result was that the assessor used the framework they know best from the rail projects: A very extensive framework, which makes sense when you assess train projects (high speed, a lot of people, etc.) but does not make a great deal of sense in projects like AM's, introducing autonomous vehicles, going an average 15 to 20 km/h, carrying a maximum of 11 people.

Hence, AMobility has spent a huge amount of time on the application material. The law is currently being evaluated, and therefore AMobility has concluded an extensive Public Affairs effort, talking to politicians, lawmakers, interest organisations and other relevant stakeholders in order to obtain another approval setup in Denmark; one that looks like the setup we know from Sweden and Norway, where Amobility works directly with the Authorities.

5.4.2.2 Vehicle Homologation

Vehicle homologation is provided by the Danish Road Directorate, based on an application that should include either an EU vehicle type approval or a single vehicle approval granted by the Danish Road Traffic Authority. Technical vehicle documentation is provided to the Danish Road Traffic Authority for Vehicle Approvals, this also includes specifications for wheelchair anchorage solutions, seatbelt, and ramps.

The NAVYA vehicles used by AMobility had thus been modified to include the required amenities.

5.4.2.3 Test Site Homologation

Given the Danish legislative framework, each route has to be approved with an individual application, including an external risk assessment and documentation regarding the implementation, operation, crisis, and risk management.

The application for each route must include the following chapters and information for homologation of each route, as shown in Table 5.3.

Table 5.3 Chapters and content for an application in Denmark

Chapter	Information
Project description	Introduction Objectives Methods Partners
Legal framework	Description of legal framework Test-framework
Vehicle description	Capabilities Capacities Technical aspects Autonomous driving
Vehicle connectivity	Basestation/N-trip 4G
Route description	Route length Schedule Garage route Depot
Bus stop description	Concessions Positions Identification
Organisation	Roles Trainers & training plans Operators Supervisors
Data description	Data handling GDPR API System descriptions
Risk handling (internal)	Risk processes Compliance Crisis management
Risk-assessment (external)	Risk identification Potential pitfalls Mitigating actions Risk process

In order to comply with the legal requirements, we had to make several adaptations to the vehicles to comply with the Danish law, like, among others, adapting the seat belts and providing access for wheel-chairs.

Regarding the seatbelts, although the NAVYA shuttle was equipped with seat belts, they were not approved/allowed in Denmark because they are not mounted according to the Danish regulations. Nonetheless they are available in the shuttle and kids and elderly are advised to use them to avoid falling during hard brakes etc.

In order to be accredited for “public transportation”, the vehicle is required to have a wheelchair ramp in Denmark. The Navya Autonom Shuttle vehicle is equipped with a manual and automatic wheelchair ramp. The manual ramp can be installed by the safety driver and the automatic ramp can be activated by an inside or outside button on the shuttle.

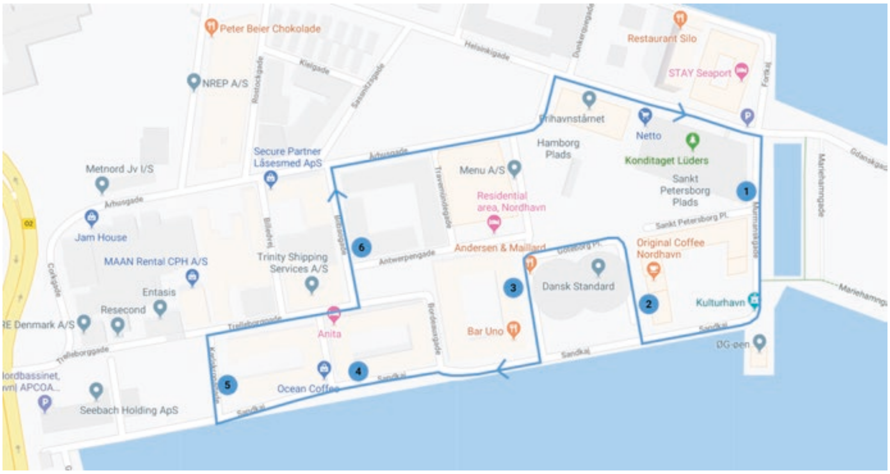


Fig. 5.5 The approved Nordhavn site in Copenhagen

For the transport of wheelchairs, a special way to fix them is required and Q-straint fixation has been installed in the shuttles. Q-straint works simply by having four mounted points in the floor, with seatbelts, that can be hooked to the wheelchair. The seatbelts retract automatically and locks when necessary. When a wheelchair has to board the shuttle, the Safety driver mounts the four seatbelt heads on the floor. This means that the floor is empty when riding without a wheelchair. When carrying a wheelchair user, the three foldable seats cannot be used, and there is room for eight additional passengers.

The adaptation of the vehicle was part of the process requirements for the final authorisation. The complete process of the vehicles and the route homologation took three years (sic!) to be completed and cost a few hundreds of thousands of EUROS. Finally, in spring 2020, the route was validated, as a fixed route with fixed bus stops, as shown in Fig. 5.5.

5.4.2.4 Nordhavn Status/Complication

Continuing the first phase of the Nordhavn site, the purpose was to expand the operating service to provide a more dense road network of routes, allowing Holo to eventually offer on-demand, door-to-door services. However, given recent developments in Nordhavn, the expansion is not possible. Due to the reality and complexity imposed by the Danish legal framework, Holo does not have the opportunity to find a new site to reach the goals of AVENUE.

The Nordhavn site is under heavy construction development, with new buildings being constructed. With a target, over the next 30 years, to become a major residential area, housing more than 100.00 inhabitants and another 60,000 workspaces. As a result, new construction sites appear all the time and some routes (streets) will be blocked during the next 3–5 years.

The current situation has forced Holo to reconsider the route in Nordhan and ask permission to divert in the project and continue operations at an alternative route. However, to obtain the authorisations necessary to deploy the Navya vehicles on another route, Holo has to start the procedure of validating the complete route from zero. Including a new assessment of the route from an approved engineering consultancy company. Historically this process has shown to be highly time consuming and Holo estimates that the process could take more than a year to complete.

The target for Nordhavn was to offer on-demand, door-to-door services, but given the construction plans and the complications of the current legal framework, it will not be possible to meet these ambitions in Nordhavn. Therefore, the site will be closed down at the end of February 2021.

Holo has been in contact with the authorities about the legal framework for autonomous trial projects. Holo has tried to start a dialogue about reviewing the legal framework, taking Holo's experience into account, but the authorities have shown no cooperation and have publicly stated that the legal framework will not be reviewed before 2022.

With the legal framework not being changed before 2022, the application of a new route with on-demand, door-to-door services could most likely take a year to get approved , leaving no time left to operate in the AVENUE project.

As a result, Holo cannot operate the services necessary in the project in Nordhavn (due to heavy construction) and the deployment of a new project with on-demand, door-to-door services cannot realistically be approved and operated before the end of the AVENUE project (April 2022).

For these reasons, Holo has to halt the operation in Nordhavn. Holo will continue to investigate potential opportunities to get the Navya vehicles back into operation, either outside of Denmark or at an already approved route in Denmark.

5.5 And the Quest Continues …

Having obtained the required authorisations to put autonomous vehicles on the street, define the routes, and instal the required technological infrastructure is only the tip of the iceberg, the first step, for the deployment of a high quality public transportation service, based on autonomous vehicles. A large number of policy decisions need to be defined and many legal issues still need to be clarified. The decisions and options defined will give rise to new passenger services, implementing the policies.

5.5.1 Transport Service Policies

A first policy (and maybe political decision) that needs to be defined concerns the ticketing and pricing of the on-demand services. Today public transportation ticketing provides a "flat rate" model for urban transportation. A ticket valid for 60 to 90 minutes or a monthly/yearly subscription allows travel to a large urban area, allowing change of vehicles and in many times change of transportation means (tram, metro, bus). This model provides an excellent approach for urban commuters and can be very well adapted to include the on-demand services. However the introduction of simple to call on-demand, door-to-door, low cost public transportation service, will create a new type of demand for trips that today are not even considered. People will start using the service for short distance AV only trips, which today are done by using other means of transport (walking, bicycle, or private car). Going to the bakery 150 meters away, walking to school 400 meters, etc. and, of course, requesting delivery at the door-step in large distance urban travel. This type of use of the service, especially since it will be free of charge, will drastically increase the public transportation kilometres and the capacity demand. The transport operator, in collaboration with the public authorities, will need to define a policy on whether to encourage or tolerate the use of AVs for short distance trips or, on the other hand, apply policies to discourage them (like higher ticket prices). However, any policy should take into account the social acceptance (an elderly person might be justified to use a short trip), and whether it can be really enforced: for example, as it was done for flight tickets, where round trip ticket was cheaper than a one-way ticket, resulting in passenger buying a round trip ticket and not using the return ticket, in AV services a passenger can reserve two trips each starting at a stop that is nearby and simply exiting in the first stop and not using the rest of the trip. Proposed solutions to this issue include identification of the passenger (via video recognition, smart-card scanning, etc.) and automatic calculation of the cost, but they raise more important issues of privacy and data protection.

A second important issue, relating directly to the business model, concerns the deployment of intervention teams. Incidents will always happen and, in the absence of a driver, a ground intervention team should be deployed and be ready to provide assistance when required. The transport operator or the public authority will need to define a maximum delay for the intervention team to arrive on the incident site, once an incident is identified. This cannot be more than a few minutes. The implications of the intervention delay will directly influence the number of required intervention teams and in consequence the operation costs of the service. What are the optimal solution needs to be defined after experience has been gained in operating a service over a long period.

5.5.2 More Legal Questions

The legal framework concerning operation of AVs in Europe is today practically non-existent. Many European countries are starting to discuss ideas and options and we expect first comprehensive frameworks to appear in a couple of years.

One of the most important issues that is under discussion concerns the management of the large mass of data collected and used by autonomous vehicles: who owns them, who can use them, where can they be used, are some of the key questions that still need a clear legal framework to be defined.

As we mentioned above, public authorities provide vehicle certifications based on the existing framework for driver-based vehicles: that is, mechanical and electrical control. However, there is no framework for the accreditation of the autonomous driver and its safe behaviour on the street. We expect that as the technology advances it will become possible for public authorities to "formally" validate autonomous drivers, possibly making a distinction of the target use cases, like for urban, low speeds, for highways, etc. Of course some questions will need to be addressed, like what happens in minor or major software updates: does the autonomous driver need to be re-evaluated or not?

5.6 The Road Ahead for the AVENUE Project

Following the authorisations to operate on-demand, door-to-door services, and based on the gained experience of more than 30 months' fixed route operations, we are in the process to develop some required passenger and transport services. Several services have been identified until now, based on experience from existing "traditional" public transportation services, and new innovative services inherent to autonomous vehicles are being identified in the project, which will be introduced and tested once we have launched the full on-demand, door-to-door services (which is the targeted AVs public transport services deployment). Currently passenger needs relate to experience from existing driver-based services. Our strategy is to provide new services without degrading the existing service quality level. We will thus first provide alternatives for services offered today by the driver (like information about stops, ticketing, assistance, etc.), then fulfil the legal requirements (like intervention teams in case of events) and next test new, innovative services.

With the new transport services under operation, we will be able to evaluate the socio-economic impact and benefits of the deployment of autonomous vehicles for public urban transport. We expect to clearly demonstrate and measurably calculate the advantages in social impact (changes of behaviour of passengers, abandoning the private car for an on-demand public transport), as well as identify the real costs of operating a large-scale AVs-based transport service, when operating at real AV conditions (that is, 18h per day, with no driver, in a fleet orchestration configuration, with intervention teams, and adapted tariffing).

Finally, the project will produce recommendations for public transport operators and authorities regarding the development and integration of autonomous vehicles in the urban and suburban transport environments, and promote the advantages of public transport autonomous vehicles to the citizens and decision makers.

In AVENUE, we strongly believe that public transportation will be the first business where autonomous vehicles will be mass deployed. The advantages, business opportunities, and potential are tremendous. AVENUE aims to open the way, change how we travel in the city, and make the use of public transportation a new experience for the passengers.

Acknowledgments This chapter was written with the contribution of Jeroen Beukers (Transport Publics Genevois – TPG, Geneva), Stine Guldmann and Christian Zinckernagel, Pernille Lytzen, Anne Rosa Simonsen, (Amobility/Holo, Copenhagen).

References

Autovista Group, "The state of autonomous legislation in Europe", 28 February 2019, https://autovistagroup.com/news-and-insights/state-autonomous-legislation-europe (visited January 2021).

Bestmile, "Bestmile: Fleet Orchestration for New Mobility Services", June 28, 2020, Company Blog, https://bestmile.com/company-blog/bestmile-fleet-orchestration-for-new-mobility-services/ (visited January 2021).

Chen, L., Ma, N., Wang, P., Li, J., Wang, P., Pang, G., et al. (2020). Survey of pedestrian action recognition techniques for autonomous driving. *Tsinghua Science and Technology, 25*(4), 458–470. https://doi.org/10.26599/TST.2019.9010018

de Veronese, L. P., Auat-Cheein, F., Mutz, F., Oliveira-Santos, T., Guivant, J. E., de Aguiar, E., et al. (2020). Evaluating the limits of a LiDAR for an autonomous driving localization. *IEEE Transactions on Intelligent Transportation Systems*. https://doi.org/10.1109/TITS.2020.2971054

EUR-Lex, REGULATION (EC) No 1370/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos 1191/69 and 1107/70, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32007R1370&from=EN

European Commission, "Guidelines on the exemption procedure for the EU approval of automated vehicles", Published on: 09/04/2019, https://ec.europa.eu/growth/content/guidelines-exemption-procedure-eu-approval-automated-vehicles_en (Visited January 2021).

HG, "Are Self-Driving Cars Legal?", HG.org, https://www.hg.org/legal-articles/are-self-driving-cars-legal-31687 (visited January 2021)

Horizon 2020 projects in the "Automated Road Transport" field, https://ec.europa.eu/inea/en/horizon-2020/h2020-transport/projects-by-field/480 (visited January 2021).

Iclodean, C., Cordos, N., & Varga, B. O. (2020). Autonomous shuttle bus for public transportation: A review. *Energies, 13*, 2917. https://doi.org/10.3390/en13112917

NAVYA, "Self-Driving Shuttle for Passenger Transportation", https://navya.tech/en/solutions/moving-people/self-driving-shuttle-for-passenger-transportation/ (visited January 2021).

Pettersson, F. "An international review of experiences from on-demand public transport services", Report number: K2 working paper 2019:5, Lund University.

SAE International – Updated Visual Chart for I "Levels of Driving Automation" Standard for Self-Driving Vehicles, December 2018, https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-"levels-of-driving-automation"-standard-for-self-driving-vehicles

Schwal, M., Daniel, T., Victor, T., Favarò, F., & Hohnhold, H. (2020). Waymo Public Road Safety Performance Data, Waymo LLC, blog report, November 2020, https://storage.googleapis.com/sdc-prod/v1/safety-report/Waymo-Public-Road-Safety-Performance-Data.pdf (visited January 2021).

TESLA, Autopilot and Full Self-Driving Capability https://www.tesla.com/support/autopilot (visited January 2021).

UITP, "Social Conditions in Urban Public Transport Companies in Europe – Final report", UITP, https://www.uitp.org/publications/social-conditions-in-urban-public-transport-companies-in-europe/ (Visited January 2021).

van de Camp, W., Kohn, A., & Radev, E., “Draft Report on Autonomous driving in European Transport”, (2018/2089(INI)), Committee on Transport and Tourism, https://www.europarl.europa.eu/doceo/document/TRAN-PR-623787_EN.html?redirect (Visited January 2021).
Vienna Convention on Road Traffic, 1968,. Chapter XI, https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XI-B-19&chapter=11

Part II
Integrating Robomobility in the Larger Perspective of Urban Mobility Innovation Embedded in Societal Contexts

Chapter 6
Recommendations for a User-Centered Design of Mobility Solutions

Ouail Al Maghraoui, Flore Vallet, and Jakob Puchinger

Abstract In this chapter, we are interested in the design and innovation processes of mobility solutions from the viewpoint of designers (vehicle providers, start-up companies developing digital mobility applications, mobility operators...). It is becoming increasingly important to take the door-to-door experience of travelers, and of other users of mobility systems, into account. Taking a step back on the research contributions of the Anthropolis chair (2016–2019), we advocate that user-centered insights are useful at different stages of solution development. When mobility solutions are not yet on the market, trials are mostly conducted to evaluate technological maturity (of autonomous shuttles for instance). Testers in these trials can say more about their experience and the value of the solution if asked to. When mobility solutions are on the market, there is a need to capture the experience of travelers and uncover their door-to-door problems through a systemic mobility diagnosis. This type of problem diagnosis can be used to feed innovation approaches, reveal value buckets for companies, and bring meaningful solutions for both travelers and the other users. Finally, we discuss the applicability and the potential of the recommendations for different mobility stakeholders.

Keywords Mobility solutions trials · Mobility problems · Design and innovation processes · User-centered mobility · Value buckets

O. Al Maghraoui
Kisio (Keolis Group), Paris, France
e-mail: ouail.almaghraoui@kisio.com

F. Vallet (✉)
Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, Gif-sur-Yvette, France

IRT SystemX, Paris-Saclay, Palaiseau, France
e-mail: flore.vallet@centralesupelec.fr

J. Puchinger
Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, Gif-sur-Yvette, France
e-mail: jakob.puchinger@centralesupelec.fr

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_6

6.1 Introduction

Taking a historical perspective, mobility in cities has changed a lot during the last 150 years. Technological developments as well as political decisions shaped its face as we know it today. It started with the large-scale introduction of public transport at the beginning of the nineteenth century (Gilbert & Perl, 2010). In the 1950s, the rise of the automobile changed the configuration of cities and their suburbs. Jones discerns three stages in the evolution of urban transport policy during the last 50 years (Jones, 2014):

- *Mobility as a flow (1930–1970)*. The first stage is characterized by the major growth in motor vehicle traffic. The approach to solve the problem of an ever-increasing number of cars was mainly driven by an engineering perspective requiring significant investment in road building and the maximization of capacity of existing street infrastructure, often at the detriment of urban light rail (street cars). These policies most often lead to a further increase in cars and car use as well as pollution and congestion.
- *Mobility as a personal trip (1970–1990)*. The second stage consisted in containing traffic and taking a personal trip perspective. The goal was to improve fluidity of road traffic and encourage the use of public transport as mass transit is orders of magnitude more efficient than individual cars. However, as cities have been further growing, only considering factors like space, time, and cost were not sufficient to accommodate further growth in peak-hour transport demand.
- *Mobility as an enabler to move -or not- (since 1990)*. In the current third stage, a livable cities perspective is taken. Social and behavioral components are taken into account, putting a greater emphasis on cities "as centers of activity and on associated urban quality of life". The primary concern becomes to allow people to meet their activity participation requirements and the movement itself becomes secondary. Such policies may encourage flexible work hours and teleworking as well as the use of home delivery of goods and a stronger focus on proximity services and businesses.

This last perspective is considered in this chapter, as developed in the next section. The objective of this chapter is to bring insights on capturing mobility usages. Indeed, understanding the complexity of mobility users is of utmost importance to anticipate the uptake, usage, and impact of new mobility solutions (shared, automated, or electric) (Axsen & Sovacool, 2019).

Most of the research presented in this chapter has been performed within the scope of the first season of the Anthropolis chair (2015–2019). Where we have been investigating user-centered eco-innovations in the context of urban mobility systems and their interactions with other urban systems.[1]*

The design science community has recently begun to consider complex systems, such as urban mobility seen as design objects (Design Science, 2020). Historically,

[1]* https://www.chaire-anthropolis.fr/

design objects consisted of artefacts, machines, software, etc. for which a designer's task is to improve or to bring new solutions to a daily life problem involving these objects. But an object that integrates multiple artefacts that evolve through time and space along a whole experience involving other users and complex social interactions is progressively becoming a serious topic that questions the fundamentals of the science of design. Fortunately, other research communities also took a holistic viewpoint of urban mobility for studying problems travelers encounter from day to day. We will therefore challenge the design paradigm with other disciplines' viewpoints and, at the same time, these other disciplines will be questioned regarding human-centered design principles. Consequently, it is important to establish the main concepts that will be used in this chapter, as it will handle multidisciplinary issues. We are considering the following concepts:

- *Mobility*: Realization of trips by users – the travelers – who conduct multiple activities (e.g., home-to-work, leisure, shopping) associated with multiple locations.
- *Travelers:* Customers of a mobility solution.
- *Mobility users*: in a broad sense, users are travelers, secondary users connected to mobility systems (e.g., bus drivers, train station agents, road users) but also the non-users.
- *Mobility problem*: a negative predicate (what goes wrong) of some referential state (expectation, satisfaction, pleasantness, wants …) for a traveler (Al Maghraoui, Vallet, Puchinger, & Yannou, 2019).
- *Mobility solution*: Product or service supporting urban mobility, notably related to electric, shared, or autonomous mobility. Also called "mobility innovation" in (Axsen & Sovacool, 2019).

The chapter highlights how the examination of mobility users and usages can feed the design process of mobility solutions at different stages. We discuss three specific outcomes from the work of the Anthropolis chair, relying on different theoretical backgrounds and addressing various target users (Table 6.1). The choice aimed at embracing a diversity of users (for instance adults but also seniors) using a

Table 6.1 Summary of the three user-centered approaches developed in the chapter

Approach	Mode	Users	Framework	Outcome
User-centered analysis of trials	Autonomous shuttle	Passengers of shuttle Pedestrians Road users	User experience design	Projection of technical issues on traveler experience
User-centered problem diagnosis	Walk, Cycle, Drive, Public Transport	Urban citizens from Paris and Vienna	Grounded theory	Mobility problem classification & causality scheme
User-centered innovation	Car-pooling	Sharers' profiles Non-sharers' profiles Focus on elderly people	Need seeker innovation	Mobility value buckets

diversity of travel modes. Excluding modes for long distance trips like plane or ship, the three studies report on the usage of most common individual, shared, and autonomous mobility solutions for short distance trips.

When mobility solutions are not yet on the market, we are firstly interested in testing and implementing. Trials are conducted, but are often examined from a technical viewpoint (for instance autonomous shuttles). There is a need to bring user-centered reflections into trials (section 6.2). When mobility solutions are on the market, incremental or radical new mobility solutions do not solve all the traditional mobility problems (waiting time, congestion, reliability, etc.). They even create new ones, regarding the complexity of a door-to-door experience of interdependent solutions. Therefore, there is a need to capture the experience of users and uncover the problems they encounter in a door-to-door setting, hence a systemic diagnosis (section 6.3). The diagnosis can be used to improve the solutions or to innovate on new solutions for both travelers and the other users (section 6.4).

6.2 User-Centered Analysis of Trials

When testers are asked to talk about their experience with a new mobility solution, they talk about the solution and how they feel about it. However, when they are asked to talk about their daily default journey and how the mobility solution changes their experience, the value of the solution and its drawbacks are uncovered. Therefore, testers help designers keep the relevant parameters and features and improve or replace the others, especially during trials when the new solution is still a prototype. This section uses autonomous shuttles as a case study to uncover the value of getting feedback from users during trials, by asking them the relevant questions and observing certain situations.

Autonomous shuttles have as main goal to fulfill the first and last mile requirements as well as micro-transit commute for city centers, central business districts, university campuses, airports, shopping malls, hospitals, and many others (Harris, 2018). Nevertheless, empirical evidence is still lacking from the point of view of user experiences (Salonen, 2018). Therefore, more trials are needed to better understand and develop relevant metrics for assessing autonomous shuttle performance not only from technical and economical standpoints, but also from social-psychological ones (Antonialli, 2021). Most of these trials are mainly intended to validate the technology for assuring reliability on both hardware (e.g. sensors) and software (e.g., decision-making) even though they involve testers who are casual pedestrians passing by the experimental site.

These testers are invited to take a ride in the vehicle and provide their feedback. However, only a few of them have ever experienced such vehicles in daily conditions in mixed traffic environments. Therefore, this feedback still does not provide usable matter to systematically improve the versions of autonomous vehicles service through the trials (without being separated from the software and hardware maturity indicators) (Nordhoff et al., 2017). There is consequently a lack of well-rounded key-performance indicators to monitor the user experience along with the maturity of the technology of autonomous vehicles (Cornet et al., 2019).

For this part, the research question is: ***"How to characterize the problems encountered by users of autonomous shuttles in mixed traffic trials?"***

Beyond the problems that autonomous shuttles inherited from public transport systems or any existing form of shared mobility solutions, some problems are specific to autonomous vehicles. For example, problems like seat discomfort or unreliable information at stations are out of scope. Indeed, problems like limited speed or obstacle detection are the ones that are investigated through literature and autonomous shuttle trial site observation.

Three types of users are affected by technical maturity problems of autonomous shuttles: passengers, road users, and pedestrians. Every technical problem has an impact on the experience of these users interacting with the autonomous shuttles. For instance, the fact that the shuttle is too slow (Kulmala, Jääskeläinen, & Pakarinen, 2019) loses value for a passenger that can make the same route on foot. Moreover, shuttles obstruct the road for road users, preventing them from driving at a normal pace. For pedestrians, slow speed can encourage them to jaywalk as they would see no danger in doing so. Figure 6.1 and Table 6.2 summarize several technical problems that directly or indirectly impact the user experience of people who interact with an autonomous shuttle. The impacts on users have been induced from interviewing AV experts, observing a trial site and interviewing a safety driver.

For example, if the technical improvement of the next prototype iteration is speed, then losing utility from the passenger experience perspective would not be an issue anymore. The improvement should obviously be considerable to the point that the passenger, regarding speed, would judge the trip duration equivalent to a bus trip

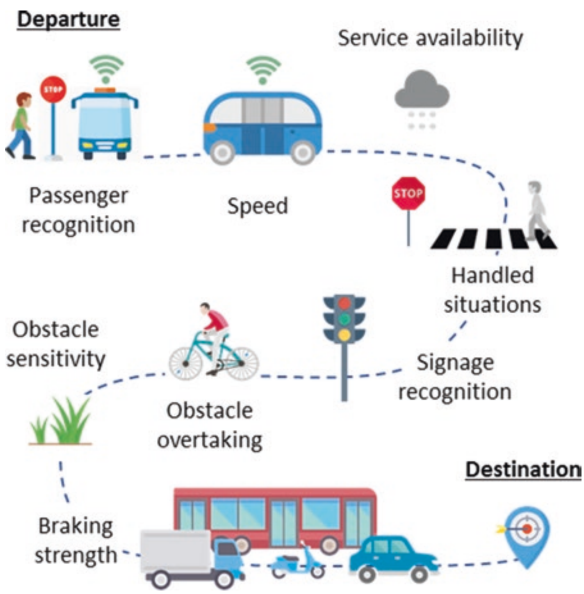


Fig. 6.1 Main technical limitations encountered by autonomous shuttles during a trial in mixed traffic

Table 6.2 Problems experienced by users in interaction with an autonomous shuttle

Technical limitation	Impact on passenger	Impact on pedestrian	Impact on road user
Too slow (max 20 Km/h) (Kulmala et al., 2019)	Losing utility (walk instead)	Encouraging jaywalking (dangerous)	Obstructing road
Requires safety driver (Cregger et al., 2018)	Losing interest (use bus instead)	Confusing (double message: AV display + safety driver)	Confusing (double message: AV display + safety driver)
No obstacle overtaking (Cregger et al., 2018)	Longing for destination	–	Obstructing road
Obstacle sensitivity too high (observed braking with no apparent reason)	Fear of non-human driving style	Confusing honks while pedestrian on sidewalk	Dangerous proximity with unexpected braking
Limited obstacle or signage recognition (observed)	Losing trust	Not being able to declare one's intention to cross the road	Not being able to communicate with the AV
No passenger recognition (Zinckernagel, Guldmann, & Lytzen, 2018)	Unsupervised misuse (e.g., dangerous posture)	-	-
Repetitive strong braking (observed)	Discomfort along the journey and motion sickness?	Not being able to know the intention of the AV	Dangerous proximity
No service available when heavy rain, snow, or fog (observed)	Unavailability of service	–	–
Some situations are not handled by the AV (observed)	Being blocked and in danger during a trip	Dangerous	Dangerous

for example. However, it is known that braking power increases with speed. Therefore, the "strong braking" discomfort will increase with speed or even will create dangerous situations within the vehicle. Consequently, an improvement of a technical aspect (speed) generates, at the same time, an improvement of utility and a deterioration of comfort and safety for passengers. So, if not taken into account, the consequences of technical improvements on users remain the same or worsen through prototype generations. This is a factor that will obstruct market adoption as long as users experience the same problems through a supposed technical evolution.

Monitoring technical maturity of autonomous shuttles helps designers identify improvements to reach the market readiness (e.g., handling a roundabout autonomously). Indeed, it is important to integrate as many regular road situations as possible so that the shuttle can compete with a human driver regarding safety for instance. However, for AV market adoption (Lavasani, Jin, & Du, 2016) and user acceptance (Pakusch & Bossauer, 2017), technical maturity has to be contextualized on the level of user experience. We identified that relevant users for autonomous shuttles are passengers, but also pedestrians and road users. Practically, starting from technical issues and projecting them on the journey of users brings out ideas on how the users will behave with the AV when ready for the market. Therefore, the next generation of the prototype will be able to include, in addition to pure technical improvements, the ability to overcome the users' mobility problems. For that matter, door-to-door mobility problems, as experienced by individual travelers, need to be framed by the different complex factors that define them.

6.3 User-Centered Diagnosis of Problems

Classical design methods help designers identify the pain points of a journey through thoughts, feelings, and actions (Osterwalder, Pigneur, Bernarda, & Smith, 2014) (p.13). However, when the systems to be diagnosed are as complex as in mobility, these methods do not consider the interdependence of the episodes of a journey, their effect on the perception of the traveler, the technical origin of the pain point, and the changing condition of the traveler. Therefore, these methods need to be completed by the knowledge of the complexity of the system to be diagnosed. Consequently, a simple problem can be transformed into a deep insight of an underperformance of the systems or an understanding of the personnel determinants that made the problem perceived as such. One way to do this is to view these mobility problems (pain points) through an archetypal model that takes into account the complexity factors of the system, the complexity of the user's condition and what happens between the system and the user. This section provides a model of travelers based on a study that has been conducted within the Anthropolis research chair (Al Maghraoui, 2019).

6.3.1 Methodology

The research methodology has been adopted from grounded theory literature (Charmaz, 2014). It starts from narratives and ends with a theory on the research question of interest. This research is intended to draw the perspective of travelers on mobility problems with minimal literature bias. Four interviews, as an initial sample, have passed through a three-stage coding process leading to an initial model as a set of categories. These interviews cover most of the transportation modes. The maximum variation sampling (Patton, 2005) has been chosen for four modes; walk, car, bike, and public transport. The four interviewees have been selected based on their modal choice for urban mobility to cover a large spectrum of mobility problems in the dimension of the used technical systems: one exclusive cycler, one exclusive pedestrian, one exclusive public transport user, and one exclusive car/motorcycle driver.

Saturation tests have then been operated on this model, using five more interviews, in order to add missing categories and enrich category definition. Eight out of the nine interviewees were urban mobility experts from different disciplines (urban sociology, transport simulation, transport engineering, urban design, and computer science). They were chosen as expert users to talk about their mobility experience within their scientific community expertise.

6.3.2 Results: Expressing Mobility Problems

Mobility problems, as perceived by travelers, are of different natures. They concern different facets of how a traveler experiences his/her usage of an urban mobility system. There are six blocks of interrelated mobility problems (Table 6.3). The state of the system, the contextual situation, and the condition of the traveler being at the origin of travel change, reaction, behavior, and measures of the traveler.

6.3.3 Illustration of an Enriched Mobility Problem Through the Mobility Problem Causality Scheme

To illustrate the use of the model, one of the problems (*P*) that has been identified from an extended interview with a bus driver of an on-demand bus service (Gilbert & Perl, 2010) is used as an example*: "Sometimes nobody answers the booking call*". It is a simple-framed problem that will be transformed into a richer causal form. (P) has been reported with two of its causes (Fig. 6.2); (**ca1**: *Lack of staff in the booking line service* & **ca2**: *High call rate during some periods of the day*) and two of its consequences (**co1**: *New users thinking the service has stopped, and giving up* & **co2**: *Regular travelers frustrated by the impossibility of making the trip as planned*. Thanks to the structuring of (P) with the causality scheme, we can infer more problems.

(P) is an accidental functional state. It is caused by another accidental functional state (ca1) and a situation involving simultaneous travelers (ca2). In (P), when nobody answers the booking call, one needs to know what happens next. He/she has an emotional reaction (co2) and a behavioral one (co1). So on and so forth, many complex causations can be induced using only an accidental functional state to see how it impacts the travelers (e.g., co23: delay of activity at destination). The same logic could be applied in deeply seeking into the causes of the technical or functional problem (e.g., ca3: a punctual person), where the traveler is less involved.

Summarily, depending on his/her condition, a traveler experiences changes in his/her travel and reacts to them. These changes can be the result of some state of the system he/she uses or some situation that is external to the system. When repeated, the changes, the reactions, the situations, and the states of the system push the traveler to take measures in his/her next trip. Following the logic of (Osterwalder et al., 2014) (p.14), telling more about usage problems (or pains) gives the designer

Table 6.3 Mobility problems definitions and examples

Block	Category	Definition	Examples
State of the system	Essential functional state	State of the system that is essential to its intended functioning	1 bus per hour, limited zone coverage
	Accidental functional state	State of the system that is accidental to its intended functioning	Late train, wrong information
	Essential technical state	State of the system that is essential to its intended design	No bag-racks, no air conditioner
	Accidental technical state	Accidental state of the system regarding its nominal state	Bad smell, slow escalator
	Technical state planning	Essential state of the system does not evolve in design or functioning	No new lines, no bus frequency increase
Situation	Situation from context	Situation provoked by external factors to the system and travelers	Rain, no-car day, train drivers strike
	Others' behavior	Situation provoked by the behavior of others	Slow walk, priority
	Simultaneous travelers	Situation provoked by travelers using simultaneously the system	Queue, no seated place available
Travel change	Active usage change	Decision-based action that a traveler takes when a change happens in expected travel	Buy coffee, find an alternative, squeeze in
	Passive usage change	Change a traveler undergoes when a change happens in his/her expected travel	Miss train, get pushed, slip
	Beyond-travel change	Change that is operated on a traveler's life before and after travel	Arrive late, miss flight, get sick
Experience measure	Avoidance measure	Measure a traveler takes to avoid a scenario that happened before	Avoid tram rail, abandon public transport
	Just-in-case measure	Measure a traveler takes to protect himself/herself from a scenario that happened before	Carry an umbrella, consider buffer
	Cognitive measure	Additional attention a traveler makes preventing a scenario that happened before	Watch one's steps, double check schedules
Traveler reaction	Behavioral reaction	How the traveler reacts to a change in his/her expected travel	Say sorry, non-respect of queues
	Emotional reaction	How the traveler reacts emotionally to a change in his/her expected travel	Irritated, mood shift, ashamed
	Physical reaction	How the traveler reacts physically to a change in his/her expected travel	Sweat, get cold, allergic reaction

(continued)

Table 6.3 (continued)

Block	Category	Definition	Examples
Condition	Psychological	How the psychological condition of traveler conditions his/her behavior before travel	Punctual, hate noise, superstitious
	Physical	How traveler is conditioned physically before travel	Weak immunity, reduced mobility
	Cognitive	How traveler is conditioned cognitively before travel	Ignoring alternatives, clumsy
	Modal	The obligation to use a specific mode or route instead of the desired one	No alternatives, no driving license
	Beyond-travel	Traveler's life condition before/after travel	No shower, a meeting

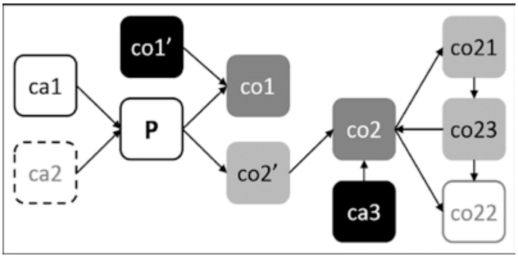


Fig. 6.2 Reformulated and enriched causality scheme of problem P

more possibilities of solutions and more relevance to the user. Indeed, the complex form of a mobility problem covers as many aspects of the traveler experience as possible.

Therefore, if the solution is thought as a problem solver, it would cover as many dimensions as possible of the mobility problems. This approach is very helpful in the identification process of innovation opportunities through a door-to-door experience of different mobility solutions and even beyond (after arrival and before departure).

6.4 User-Centered Innovation

In order to characterize how practitioners implement innovation in early innovation phases, (Kleinsmann, Valkenburg, & Sluijs, 2017) emphasized four main strategies: purpose-driven innovation, value-driven innovation, vision-driven, and experience-driven innovation. In this section, we are more specifically interested in experience-driven innovation, i.e., innovation aimed at imagining rich experiences in co-creation with users. This can also be called a "need seeker strategy" (Jaruzelski, Staack, & Goehle, 2014). In this context, it is argued that a tangible way to model the design problem is to focus on *user pains or problems* in their activities (Yannou, 2015) (Lamé, Yannou, & Cluzel, 2017). This is the foundation of the need-seeker methodology called Radical Innovation Design®, which was applied to following mobility project. This section sheds light on how the deep knowledge of mobility problems and activities can lead to promising areas of value creation for mobility services ("value buckets") and hence feed solutions and business design.

6.4.1 Methodology

The innovation project called Mooment was conducted in 2017 with a team of five students (originating from engineering, business, and industrial design curricula) over a period of eight weeks. The project was part of a masters' level course on radical innovation integrated to the engineering curriculum. The working time dedicated to the project encompassed 120 hours for students, who had to do a final pitch in front of 25 innovation experts from industry and academia. The innovation brief was elaborated by industrial partners and researchers of the Anthropolis chair, who is interested in user-centered innovations for urban mobility. The coaching was ensured by two of the authors of the paper, also part of the Anthropolis team.

The fundamentals of the Radical Innovation Design® methodology are detailed in the following papers: UNPC (Usefulness, Newness, Profitability, Concept) indicators for project selection (Yannou, Farel, Cluzel, Bekhradi, & Zimmer, 2016); Dependency Structure Modeling Value bucket (Yannou, Cluzel, & Farel, 2016). In a nutshell, the Radical Innovation Design methodology puts a great emphasis on the problem design stage. To this end, it encapsulates a systematic analysis of problems arising in typical usage situations and for which efficient existing solutions are lacking. The approach proposes an algorithm for processing problems, situations, and existing solutions categorized form observations and resulting in the so-called value buckets, starting points of ideation stage. More insights on applicative examples of the method can be found as follows: smart lighting project (Bekhradi, Yannou, Cluzel, & Vallette, 2017); healthcare innovation project (Lamé et al., 2017).

The innovation brief tackled shared mobility activities, with the intention to increase the proportion of sharing practices. The brief also raised the need to question why people share under some circumstances while they do not wish to share in other contexts. The main outcomes of Mooment will be exposed in the paper, starting with Problem and Knowledge design, followed by Solution and Business Design.

6.4.2 Results: Innovating for Shared Mobility

6.4.2.1 From the Initial Idea to the Definition of Value Buckets

The ideal goal was set as follows: *"Determine why some people are reluctant to share mobility solutions, while creating social links in everyday life and reducing our collective environmental impacts"*.

With shared mobility, users benefit from a short-term access to shared vehicles (car, scooter, bike, etc.) according to their needs, instead of requiring vehicle ownership (Shaheen & Chan, 2016) or sharing rides (ride-hailing or car-pooling). Shared mobility is also characterized by the use of technology (through applications and the internet) to connect users and providers (Santos, 2018). Moreover, it can be noted that emotions are also an interesting immaterial dimension which may be shared between people in their daily life.

In a first step, families of shared *mobility solutions* were established. Thanks to the visit to the Autonomy mobility event and the different information gathered in the knowledge design phase, five main families of shared mobility solutions were stated as follows: co-mobility (e.g., ride-sharing motorbike-sharing, walk-sharing); shared vehicles (cars or bikes); vehicles with a driver (e.g., taxi), public transportation; complementary sharing services refer to shared parking or co-working spaces. Note that public transportation was considered as part of the solutions since it allows people to share space and transportation mode.

Second, categories of *mobility profiles* were also generated. Attitudes of people towards the practice of sharing in everyday life are miscellaneous and uncover multiple nuances. In the transport literature, mobility profiles allow to capture the great diversity of mobility habits or behaviors through the creation of meaningful categories, which depend upon the investigated issue. Mobility profiles can be mode-based, trip purpose-based, or gender-based (Pronello & Camusso, 2011). In this project, we are interested in the propensity of people for sharing at two different levels: in their general way of life, and also in their mobility habits. Three main categories of profiles were qualitatively created by crossing sharing and mobility attitudes, based on (CNIL, 2016) and (Belot, 2011): Sharers are people committed to sharing in their daily life and mobility ("Committed", "Smart Consumers", "Thrifties", "Emotionals"); Unconscious sharers who are prone to share in some occasions, but without being aware of it ("Young", "In a rush"); Non-sharers are not convinced by sharing out of insecurity, lack of confidence, or reluctance to technology, for instance ("Non-tech savvy", "Independent", "Reluctant", "Fragile"); they mostly rely on individual cars or taxis for their mobile life. Finally, ten profiles were created and enriched by motivations in life, and typical mobility solutions which could be adopted by each representative of a profile.

Third, a systematic examination of twelve typical daily situations for sharers, non-sharers, and unconscious sharers conducted to eight main sources of *mobility problems* associated with sharing. This was crossed with data of a sample of 15 people questioned through an online survey, ten users and eight professionals from the field of shared mobility during live interviews. The sources of problems are defined as follows: lack of trust related to the reliability on the accomplishment of the journey; lack of comfort: physical satisfaction of the traveler; feeling of insecurity: physical and psychological safety and protection; feeling of deprivation of freedom; concern about intimacy related to privacy and property of data; lack of practicality; lack of knowledge, i.e. difficulty to cope with the technology employed (cars, apps, etc.); economical concern.

Finally, mobility situations, problems, and current solutions were introduced as input data in the DSM Value Bucket algorithm, which highlights the critical problems and situations that are currently not alleviated thanks to existing solutions. The most impactful *value bucket* that seems to emerge is the lack of knowledge or know-how when trying to subscribe to some shared mobility platforms. The lack of knowledge is also an important value bucket in the situation where someone is looking for means of social interactions. In addition, we can see that people tend to be confronted to a feeling of deprivation of freedom when they have to travel door-to-door, which also seems to be an important value bucket. This knowledge intensive phase of investigation and problem framing conducted to a strategic stage where the value buckets were carefully examined with the industrial partners to focus on a promising area of value creation, called *ambition perimeter*.

6.4.2.2 From the Ambition Perimeter to the Business Design of an Innovative Solution

In order to frame the ambition perimeter, an additional constraint on the type of urban area was added at this stage. Peri-urban areas were targeted since sharing mobility seems a greater issue, and also a more relevant solution in less dense areas (Brimont, Demailly, Saujot, & Sartor, 2016). This perimeter was set as *"Provide shared mobility while decreasing the feeling of insecurity and restoring social links in peri-urban areas"*.

After a session of idea generation, 30 ideas were generated, filtered, and clustered into five different concepts. The UNPC (Utility Newness Profitability Concept) model was used to rate and compare the concepts. Among all the solutions, the *Ride sharing button* gathered the highest range of proofs in all the categories. It is also assumed to be the solution with the highest potential impact on pain relief. The second strategic choice was to target "Non tech savvy" profiles, and more specifically elderly people who are still mobile. To account for this choice, it is stated that 75–85-year-old people (4.5 million in France) are potentially losing their autonomy (Keoscopie, 2016). Moreover, if people over 75 are more numerous than teenagers, their opinion about mobility is less considered in the public debate.

"Mooment" is a unique word which stands for Moment, Move and Mood. Three ideal scenarios were framed for the ambition perimeter. For instance, in one of the scenarios, the elderly person can use a shared mobility service without giving any private information. Mooment aims at connecting two types of user profiles: elderly people who are supposed to be non-sharers, and sharers in their neighborhood, who are ready to help. It may lastly involve one relative of the elderly person. Figure 6.3 gives an overview of the salient steps conducted to develop the shared mobility concept. The user experience created by Mooment can be narrated as follows:

"Mooment allows elderly people with mobility problems like Janette, 84 years old, to do their everyday trips thanks to shared mobility with her neighborhood. She can be driven to the market, the doctor or at her friend Paul's house by just pushing a button. Janette feels safe enough to go out, and less lonely because she meets nice

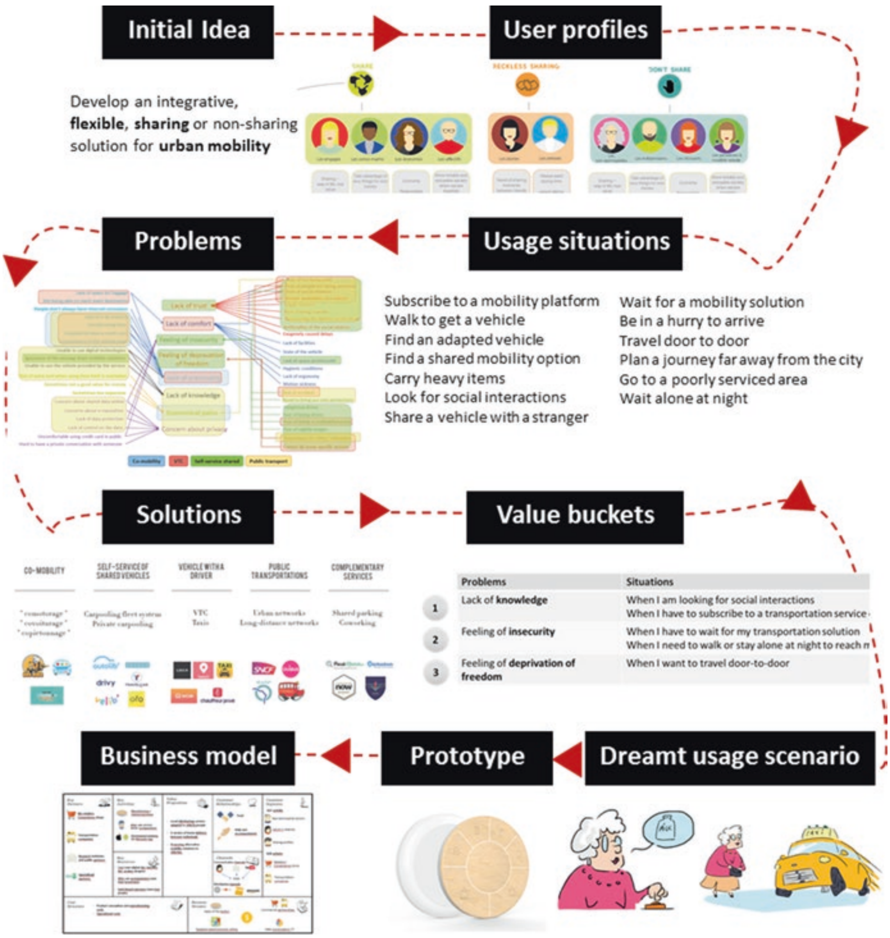


Fig. 6.3 Overview of Mooment innovation project

people and she creates new social links. She can also ask for a home-delivery to alleviate pains related to daily tasks and to avoid moving for a simple bottle of milk. Mooment is a service which gives access to additional alternative forms of mobility (VTC, other ridesharing services…) if a ride is not available on time. Indeed, it is extremely important to have a backup solution if there are not enough ride offers available (Keoscopie, 2016). This service works with an easy-to-use device to face the reluctance towards technology. It consists of a simple support in the form of a button allowing a person A to send: one request of ridesharing to all the people owning a matching phone application in a defined area; One request for a particular service, shopping groceries for instance. If person B is willing to acknowledge the request, a phone call is established, without having to share one's phone number, and A and B agree on the details of the ride/service. If no one is answering A's request, Mooment suggests another transportation service, and deals with the order procedure for the elderly person."

In summary, we showed that a need seeker innovation approach like Radical Innovation Design® is appropriate to innovate for shared mobility. This approach is based on a deep understanding of users, usage problems and situations associated with shared mobility. Several user profiles were more specifically identified depending on their ability to share – or not – mobility, but also objects, habits, emotions in their daily life. A great potential of innovation was revealed for elderly people living in peri-urban areas.

6.5 Discussion

In this part, we firstly discuss the potential of a user-centered approach for key mobility stakeholders. It is followed by a brief discussion on the impacts of a major global sanitary crisis like Covid-19 pandemic on users and mobility behaviors.

For urban planners, policymakers, and mobility practitioners, engaging in a Sustainable Urban Mobility Plan (SUMP) process means placing a great emphasis on citizen and stakeholder's involvement (Wefering et al., 2014). We therefore suggest that user-centered analyses introduced in the chapter could partly feed SUMP Phase 1- step 3-Analyze mobility situation and provide scenarios. This phase is dedicated to analyzing the current status (i.e., deficits, problems, and opportunities) regarding urban mobility development for passengers and freight, also including resilience towards expected and unexpected events (Wefering et al., 2014) (p. 40).

For a transportation operator, several barriers are associated with the adoption and spread of a user-centered approach. A major reason is the tension between operational excellence and user experience. For transport operators, operations are the core business. For this reason, their key performance indicators are operation-based. Their contract with their clients, the mobility organizing authorities, is also based on pure operations excellence indicators such as regularity and punctuality to which contractual penalties are attached. Sometimes, these contracts might include customer satisfaction which is generally just a score for the user to rate his/her appreciation of the mobility service. Consequently, both functions that a transport operator designs for its services and requirements towards its suppliers are not centered on the user experience. This fact directly impacts the whole organization and its culture. There are two legacy mindsets that are user-related and concern the traveler experience: user experience (UX) and customer experience.

1. **UX design of digital interfaces vs User experience of whole system.** UX design engage neither the door-to-door experience of travelers nor their concerns that are not directly connected to the digital interface they interact with. Consequently, UX design misses value creation around many aspects happening during or before/after a trip, when a traveler is not interacting with the digital interface. For this reason, the user experience of the set of systems that travelers

interact with can bring more insights to a transport operator than just using UX on digital interfaces.

2. **Customer experience and satisfaction vs User experience**: For transport operators, marketing departments play a central role, as they are studying travelers as being customers. Therefore, the customer perspective has a heavy “boutique” connotation, meaning that the traveler is the payer and the objective is to make him/her pay more, while being satisfied. Frequently, it is not the job of the marketing departments to uncover user experience issues that are meant to be transformed to recommendations of the next generation of buses, for example. Design requirements are usually communicated from vehicle or digital solutions suppliers. Solution designers are mainly engineers who respect technical functional specifications.

We can conclude that, in an industrial context, it is challenging to bring a traveler-centered mindset to historical jobs that see the traveler differently from a user of several systems in a door-to-door experience. However, it is also important to be aware of the conversions to be operated towards each of these “legacy” perspectives on the traveler, to demonstrate the additional value that can be created with having a user/traveler centered mindset.

Compared to the framework proposed by (Axsen & Sovacool, 2019), our focus is limited to personal or individual mobility experiences providing both functional and symbolic perceptions and does not cover more societal problems (e.g. social equity, environmental impacts). However, our attempt is to embrace a diversity of usages by considering several user groups – including non-users – regarding the mobility solutions.

To close this section, we discuss the potential implications of Covid-19 on mobility behavior across modes, in a worldwide perspective. Studies published soon after the first Covid-19 episode in the spring of 2020 report a dramatic decrease in the daily mobility, together with an uptake of teleworking (Colard, Ni, & Meilhan, 2020; Forum Vies Mobiles, 2020; Kisio, 2020). The propensity to move less was all the more important with ageing, older people becoming far less mobile than they used to be (Paquier, 2021). Unsurprisingly, the fear of contamination became a primary concern for individuals to choose their mobility mode, in front of traditional factors like travel time or convenience (McKinsey, 2020a).

Mobility habits are expected to be impacted in the long term after the first crisis event and significant modal shifts can already be observed. At a national level, urban dwellers in France tend to turn away from public transport for the benefit of private car (30%), micro-mobility or cycling (25%) and walking (40%); in the meantime, some scooter users or cyclists turn to private car usage (Paquier, 2021). Globally, public transport has lost its attractiveness and experienced a decrease of 70% to 90%, which is also true for ride-hailing (60–70%) (McKinsey, 2020b). As pointed out by (Corwin, Zarif, Berdichevskiy, & Pankratz, 2020), the combination of pandemic and economic fallout raises, amongst others, three fundamental questions to address in the mobility field: (1) What happens to shared mobility? (2) How do public transit systems cope? (3) How many trips will be permanently replaced by virtual, remote alternatives?

6.6 Conclusions and Future Work

The future of public transport cannot be imagined in isolation of other mobility solutions, as it is emphasized in the MaaS concept. The aim of this chapter was to highlight how examining mobility users and usages can feed the design process of mobility solutions at different stages, also including the usage of public transportation. Indeed, carefully defining and understanding users in mobility situations is not as easy as it seems (Axsen & Sovacool, 2019). This is specifically challenging for designers of mobility solutions, mobility operators, but also for decision makers. We advocate for the analysis of mobility problems as a powerful way to enrich the design of new mobility usages and solutions. We more specifically propose to:

- Link mobility problems encountered by passengers, pedestrians, and road users to technical limitations in the case of autonomous shuttle trials
- Propose a descriptive taxonomy of mobility problems experienced by travelers in door-to-door situations, whatever the mode used
- Identify the most frequent mobility problems for categories of users in specific situations as a lever to innovate, in the case of shared mobility

Lessons can also be learnt when taking a look at the impacts of a health crisis on mobility usages and habits of people, which may be dramatically affected all over the world, in the short and long term. We are facing an urge to design resilient mobility solutions and thus consider the risks linked with unexpected events in the user-centered design approaches for mobility. This indeed opens up avenues for new multidisciplinary research studies to strengthen our recommendations regarding the analysis of mobility problems.

In line with (Wefering et al., 2014) (p. 7), we believe that a sustainable planning of our future cities should be centered on citizens: *"citizens as travelers, as businesspeople, as consumers, customers or whatever role one may assume, people must be part of the solution"*.

Acknowledgments The authors wish to thank students who actively participated to Mooment project (Nathalie Butez, Alexandra Lakermance, Simon Lepiniec, Belen Marti et Bruna Habib-Cavazza), and Mirna Ojeda Benitez for her master research work on the analysis of trials with autonomous shuttles in mixed traffic. This research work has been carried out in the framework of the Technological Research Institute SystemX, and therefore granted with public funds within the scope of the French Program "Investissements d'Avenir".

References

Al Maghraoui, O. (2019). Designing for urban mobility – Modeling the traveler experience, (Chapter III) thesis, *Laboratoire Genie Industriel - Paris Saclay University.* http://www.theses.fr/2019SACLC006/document

Al Maghraoui, O., Vallet, F., Puchinger, J., & Yannou, B. (2019). Modeling traveler experience for designing urban mobility systems. *Design Science, 5*, E6. https://doi.org/10.1017/dsj.2019.6

Antonialli, F. (2021). Autonomous shuttles for collective transport: a wordwide benchmark. *International Journal of Automotive Technology and Management, 21*(1/2), 5–28.

Axsen, J., & Sovacool, B. K. (2019). The roles of users in electric, shared and automated mobility transitions. *Transportation Research Part D: Transport and Environment, 71*, 1–21. https://doi.org/10.1016/j.trd.2019.02.012

Bekhradi A., Yannou B., Cluzel, F, & Vallette T. (2017). Categorizing users pains, usage situations and existing solutions in front end of innovation: the case of smart lighting project. *21st International Conference on Engineering Design (ICED 17)*, Vancouver, Canada. https://hal.archives-ouvertes.fr/hal-01665096/document

Belot, L. Le Monde. (17 octobre 2011). Le partage, un nouveau mode de consommation. Accessed 24/06/2020. https://www.lemonde.fr/vous/article/2011/10/17/le-partage-un-nouveau-mode-de-consommation_1589044_3238.html

Brimont L., Demailly D., Saujot M., & Sartor O. (2016). Mobilité collaborative : des promesses aux enjeux pour les pouvoirs publics. [Online]. https://www.iddri.org/fr/publications-et-evenements/policy-brief/mobilite-collaborative-des-promesses-aux-enjeux-pour-les

Charmaz, K. (2014). *Constructing grounded theory*. Sage. https://uk.sagepub.com/en-gb/eur/constructing-grounded-theory/book235960

CNIL. (2016). Cahier IP 4 Partage. [Online] https://linc.cnil.fr/fr/cahier-ip4-partage

Colard, J., Ni, J., & Meilhan, N. (2020). Mobilités et COVID-19: Quels im-pacts sur les comportements et les politiques de transport?, *Point de vue, Paris: France Strategie.*

Cornet, H., Stadler, S., Kong, P., Marinkovic, G., Sathikh, P. M., & Frenkler, F. (2019). User-centred design of autonomous mobility for public transportation in Singapore. *Transportation Research Procedia, Volume, 41*, 191–203. https://doi.org/10.1016/j.trpro.2019.09.038

Corwin S., Zarif R., Berdichevskiy A., & Pankratz D. (2020). The futures of mobility after COVID-19.. Scenarios for transportation in a post-coronavirus world. https://www2.deloitte.com/us/en/insights/economy/covid-19/future-of-mobility-after-covid-19-transportation-scenarios.html/

Cregger, J., Dawes, M., Fischer, S., Lowenthal, C., Machek, E., & Perlman, D. (2018). Low-speed automated shuttles: State of the practice. Final Report (No. FHWA-JPO-18-692). https://rosap.ntl.bts.gov/view/dot/37060

Design Science. (2020). Design and mobility collection (since 2016) Cambridge University Press. https://cambridge.org/core/journals/design-science/collections/design-and-mobility

Forum Vies Mobiles. (2020). Enquête sur les impacts du confinement sur la mobilité et les modes de vie des Français. https://fr.forumviesmobiles.org/projet/2020/04/23/enquete-sur-impacts-confinement-sur-mobilite-et-modes-vie-des-francais-13285

Gilbert, R., & Perl, A. (2010). *Transport revolutions: Moving people and freight without oil* (2nd edn). Routledge, https://www.routledge.com/Transport-Revolutions-Moving-People-and-Freight-Without-Oil/Gilbert-Perl/p/book/9781844076987

Harris, R. (2018). Shuttle diplomacy: The path to deployment.. Transportation-As-A-Service, https://www.publishing.ninja/V4/page/4572/245/270/1

Jaruzelski, B., Staack, V., & Goehle, B. (2014). Proven paths to innovation success. *Tech & Innovation, 77*, 2–16. https://www.strategy-business.com/article/00295?gko=8a0a5

Jones, P. (2014). The evolution of urban mobility: The interplay of academic and policy perspectives. *IATSS Research, 38*(1), 7–13. https://doi.org/10.1016/j.iatssr.2014.06.001

Keoscopie. (2016). Enquête Keoscopie – Un regard éclairé sur la mobilité.. Document available online under https://www.slideshare.net/Keolis/keoscopie-un-regard-clair-sur-la-mobilit

Kisio. (2020). COVID-19: Confinement et mobilités. *Kisio, 10 April 2020,* https://kisio.com/uploads/2020/04/20200410-Confinement-et-Mobilit%C3%A9s-VF.pdf
Kleinsmann, M., Valkenburg, R., & Sluijs, J. (2017). Capturing the value of design thinking in different innovation practices. *International Journal of Design*, *11*(2), 25-40. http://www.ijdesign.org/index.php/IJDesign/article/view/2771/780
Kulmala, R, Jääskeläinen, J., & Pakarinen. S. (2019). The impact of automated transport on the role. In *Operations and costs of road operators and authorities in Finland.* https://www.traficom.fi/sites/default/files/media/publication/EU_EIP_Impact_of_Automated_Transport_Finland_Traficom_6_2019.pdf
Lamé, G., Yannou, B., & Cluzel, F. (2017). Usage-driven problem design for radical innovation in healthcare. *BMJ Innovations, 4*(1), 15–23. https://doi.org/10.1136/bmjinnov-2016-000149
Lavasani, M., Jin, X., & Du, Y. (2016). Market penetration model for autonomous vehicles on the basis of earlier technology adoption experience. *Transportation Research Record, 2597*(1), 67–74. https://doi.org/10.3141/2597-09
McKinsey Center for Future Mobility. (2020a). Five COVID-19 aftershocks reshaping mobility's future: The pandemic will change the face of mobility, both now and when the crisis ends, *McKinsey,* September 2020.
McKinsey Center for Future Mobility. (2020b). The impact of COVID-19 on future mobility solutions: As the global pandemic spreads, mobility players need to prepare for the new world ahead, *McKinsey*, May 2020.
Nordhoff, S., Van Arem, B., Merat, N., Madigan, R., Ruhrort, L., Knie, A., & Riender H., (2017). User Acceptance of Driverless Shuttles Running in an Open and Mixed Traffic Environment. *12th ITS European Congress*, no. June: 19–22. https://www.researchgate.net/publication/317497564
Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2014). *Value proposition design* (Vol. 1). Hoboken, NJ: Wiley.
Pakusch, C., & Bossauer, P. (2017, July). User acceptance of fully autonomous public transport. In *ICE-B* (pp. 52–60). https://doi.org/10.5220/0006472900520060
Paquier, J. (2021). Il faut redonner de la confiance dans le transport public. *Journal du Grand Paris, January 2nd*. https://www.lejournaldugrandparis.fr/y-dupuis-keolis-il-faut-redonner-de-la-confiance-dans-le-transport-public/
Patton, M. (2005). Qualitative research. *Encyclopedia of Statistics in Behavioral Science, 3*, 1633–1636. https://doi.org/10.1002/0470013192.bsa514
Pronello, C., & Camusso, C. (2011). Travellers' profiles definition using statistical multivariate analysis of attitudinal variables. *Journal of Transport Geography, 19*(6), 1294–1308. https://doi.org/10.1016/j.jtrangeo.2011.06.009
Salonen, A. O. (2018). Passenger's subjective traffic safety, in-vehicle security and emergency management in the driverless shuttle bus in Finland. *Transport Policy, 61*, 106–110. https://doi.org/10.1016/j.tranpol.2017.10.011
Santos, G. (2018). Sustainability and shared mobility models. *Sustainability, 10*, 3194. https://doi.org/10.3390/su10093194
Shaheen, S., & Chan, N. (2016). Mobility and the Sharing Economy: Potential to Overcome First- and Last-Mile Public Transit Connections. *UC Berkeley: Transportation Sustainability Research Center*. https://doi.org/10.7922/G2862DN3
Wefering, F., Rupprecht, S., Bührmann, S., Böhler-Baedeker, S., Granberg, M., Vilkuna, J., et al. (2014). *Developing and implementing a sustainable urban mobility plan guidelines*. Brussels, Belgium: European Commission.
Yannou, B. (2015). Supporting need-seeker innovation: The radical innovation design methodology. *20th International Design Conference on Engineering Design (ICED'15)*, Milano, July 27–30, Italy. https://hal.archives-ouvertes.fr/hal-01340338
Yannou, B., Cluzel, F., & Farel, R. (2016). Capturing the relevant problems leading to pain- and usage driven innovations: The Dependency Structure Modeling Value Bucket algorithm. *Concurrent Engineering,* (October). https://doi.org/10.1177/1063293X16666311

Yannou, B., Farel, R., Cluzel, F., Bekhradi, A., & Zimmer, B. (2016). The UNPC set of indicators for idea or project selection and maturation in healthcare. *International Journal of Design Creativity and Innovation, 5*(3–4), 205–221. https://doi.org/10.1080/21650349.2016.1161562

Zinckernagel, C., Guldmann, S., & Lytzen, P. (2018). AVENUE autonomous vehicles to evolve to a new urban experience D 2.1 first gap analysis and recommendations on autonomous vehicles for public service. https://h2020-avenue.eu/sites/default/files/documents/h2020-avenue_deliverable_d2.13_services_final.pdf

Chapter 7
The Integration of Innovative Mobility into the Urban Transport Network: A Literature Review

Ayman Mahmoud, Tarek Chouaki, and Jakob Puchinger

Abstract In this chapter, we investigate the potential integration of innovative mobility modes with urban public transport. We emphasize the design of future autonomous on-demand transport systems in the future and the interactions of these systems with public transport. These new modes pose several implementation challenges for public transport system design, including strategic, tactical, and operational choices when projecting the implementation. The impact on the overall urban transport systems is considered along with sustainability. We will review the current literature and state of the art, investigate technological developments, and finally develop some visions and research perspectives on the future integration of on-demand transport in public transport systems.

Keywords Autonomous vehicles · Shared mobility · Electrification · Innovative mobility

A. Mahmoud (✉)
Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, Gif-sur-Yvette, France
e-mail: ayman.mahmoud@student-cs.fr

T. Chouaki · J. Puchinger
Université Paris-Saclay, CentraleSupélec, Laboratoire Génie Industriel, Gif-sur-Yvette, France

Institut de Recherche Technologique SystemX, Palaiseau, France

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_7

7.1 Introduction

Economists used to believe that modern telecommunication systems would render commuting redundant. However, the need to move around remained a necessity in our everyday lives, resulting in public transport's continued use (Nilles, 1978).

The current tech-driven disruptions, which are changing ownership ideals and how we move in a city, result from new mobility technologies, such as Autonomous Vehicles (hereafter AV), and new forms of the economy, such as smart payment systems, virtual wallets, and shared economy. In this context, we consider the role of innovative mobility in updating public transit, thus making it capable of serving an ever-growing global population. An overall perspective would indicate that the introduction of new mobility modes into the urban transport network poses two main challenges:

- **Establishing Mobility as a Service (MaaS):**
  One of the first definitions of MaaS was "a system in which a comprehensive range of mobility services are provided to customers by mobility operators." MaaS integrates various transport services into a single mobility service accessible on demand (Arias-Molinares & García-Palomares, 2020).
- **Making Micro-transit Mainstream:**
  Micro-transit is defined as a privately or publicly operated, technology-enabled transit service that typically uses multi-passenger/pooled shuttles or vans to provide on-demand or fixed-schedule services with either dynamic or fixed routing ((J3163) SAE, 2018).

In the following sections, we investigate the research advances to integrate innovative mobility through a top-down review. Starting with strategic, tactical, then operational perspectives, we present real-world examples and use cases of integration of innovative mobility. These actual applications give us a preliminary hint of the impact of new innovative mobility systems and the findings based on these real-life experiments. We also present our recommendations and identify the research gaps.

7.2 Research Efforts Innovative Mobility and Public Transport

Connections between innovative mobility and public transit aim to scale-up public transit with new mobility to accommodate the ever-growing demand.

We split the research into three themes. The first of which entails a strategic point of view and adequate long-term decision-making. We pose questions on integrating new innovative mobility modes; we display the public's preferences, modes to consider, and the potential barriers to integration.

In the second theme, we present the research from a tactical point of view. We address problems for the short-term processes, such as the deployment plan and mixed traffic planning, the integration of charging stations in road networks, the fleet sizing, and demand simulation of new innovative mobility solutions with public transit.

In the third theme, we present the research work done from an operational perspective to respond to day-to-day operational questions on the best routing algorithms for intermodal mobility. In the last section, we reflect on the work done and synthesize the existing innovative mobility integration.

7.3 Strategic Perspective

The integration of new mobility modes directly relates to intermodality (using more than one mode for a single trip). Intermodality is regularly alluded to as a measure to help achieve more sustainable mobility.

A range of studies describes the integration of innovative smart mobility with current public transport (Hereafter PT) modes, potentially leading us to an intermodal trip planning scheme. The strategy of deployment of new innovative mobility remains unclear. The reason is twofold:

- **Deployment Strategies and Policies:**
  Effective policies to deploy new innovative mobility is (are) not defined. The measure of potential barriers to the strategy of deployment is based on empirical findings that are hypothetical. There is, however, research effort related to this subject (Fagnant & Kockelman, 2015; Krueger, Rashidi, & Rose, 2016; Nazari, Noruzoliaee, & Mohammadian, 2018).
- **Potential Barriers to the Deployment:**
  A potential barrier can be identified, which is an introduction to the market. A challenge can be surmised in the face of the normalization of innovative mobility technologies, which is the psychological attitude toward AV technology.

The new mobility concepts should adapt to the current infrastructure. The upgrade of infrastructures, such as the roads or subway, is costly and takes years to finish (Salazar, Rossi, Schiffer, Onder, & Pavone, 2018). Therefore, mobility modes that use existing routes, such as AVs (technology), will be much more attractive to deploy in cities than the Hyperloop (technology) concept.

However, we should look at studies on user behavior and adoption for insights into possible strategic decisions—the research effort to capture user preference and choices. For instance, waiting time will be one of the main factors in accepting new mobility modes (Krueger et al., 2016).

When it comes to first and last-mile solutions, new mobility modes could potentially complement PT Networks (Nazari et al., 2018). However, new mobility modes can also be perceived as a threat to the existing PT networks if it offers more convenient options at a competitive price. The emerging green mobility patterns are also seen as a deciding factor in the new mobility solutions. We see many individuals who make their mobility choice based on their impact on the environment and also prefer green modes such as walking or biking instead of riding an autonomous shuttle (Krueger et al., 2016). The solution will come to a point to define the behavioral model of the riders.

Simulation can be a tool to aid strategic decisions on mobility systems. For example, research shows how a service based on self-driving cars can improve public transportation in Switzerland's rural areas (Sieber, Ruch, Hörl, Axhausen, & Frazzoli, 2020).

The strategy of deployment will depend on the social demographic and other unaccounted latent factors. The most impactful latent factors are safety concerns related to new mobility modes, green travel patterns being adopted, and tech-savviness (Nazari et al., 2018).

There is a need to design effective transport policies that aim to realize the potential benefits of (Shared) Autonomous Vehicles (Hereafter SAVs). Researchers try to use public preferences as an input into the modeling of privately owned AVs and multiple SAVs configurations based on the trip's purpose (Krueger et al., 2016; Nazari et al., 2018). They also treat the possible mobility patterns and adoption behaviors across the (S)AV types caused by potential unobserved factors such as user willingness to wait for an SAV service and the travelers' acceptance to be in a cabin without a driver.

The empirical results in the research suggests that deployment choice will depend on the urban mobility scheme's social demography. Research also confirms that private vehicle ownership will become redundant (Krueger et al., 2016).

The deployment of mobility services that rely on sharing commutes brings us to an exciting point on the logic of collective action (Olson, 1971). The hidden cost of shared mobility and an invisible potential barrier is how much time people are willing to use a shared ride mobility mode, especially when non-shared mobility is available and affordable, such as mobility on demand (MOD) taxis. Many services and last-mile solutions already exist, such as free-floating micro-mobility (City bikes) that can be more appealing than SAVs for users adopting greener mobility patterns.

A range of research work captures users' willingness to adopt this mobility and the apparent cost vs. waiting time incentives. The study also introduces many exciting methods such as green mobility patterns, behavioral change, and the overall experience design (Zijlstra, Durand, Hoogendoorn-Lanser, & Harms, 2020). Regarding MaaS, for example, an analysis based on semi-structured interviews conducted in England identified five core themes as playing a significant role in the acceptance of MaaS (Alyavina, Nikitas, & Tchouamou Njoya, 2020):

– **Car dependence:** For most users, MaaS services could not replace the convenience of privately owned cars, but some of them stated that it would affect their driving habits.
– **Trust:** Many interviewees doubted that MaaS would be as efficient as advertised or that the service's information wouldn't be accurate, especially with en-route

issues. Others were more concerned about the technologies that MaaS relies on, from mobile phone battery life to cybersecurity issues.
- **Human element externalities:** This theme groups the issues raised by negative human behavior resulting from other users or the service providers, e.g., negligence, discourtesy, and disobedience.
- **Value:** For people to switch to MaaS, they have to see an added value in it. The ability to access the service through one mobile application was exciting for many participants. The utility of MaaS for leisure and tourism was also identified.
- **Cost:** This concern was raised by some participants even before a specific question about it was asked. The views on how much MaaS cost differed, some wanted to reduce the cost of their travels, while others didn't mind paying a bit more for the additional services offered in MaaS.

We also investigated studies that mix ride-sharing with public transport, from routing problems to design and feasibility studies. One of the notable early investigations done in this area is the report Ride-sharing as a Complement to Transit (Transportation Research Board and National Academies of Sciences, 2012). This report highlights ride-sharing as an essential opportunity for transportation agencies to address the last mile problem. It shows a comprehensive survey on transit agencies in the united states trying to close service gaps and to penetrate areas where it is challenging to use public transit facilities using ride-sharing.

The strategy of deployment will be concerned with tech-savviness. Users should be aware of these new technologies' security levels since research work showed a global concern over the system's safety and the idea of being in a vehicle with no driver (Nazari et al., 2018).

There exists a research gap in modeling strategies that are concerned with the integration. As far as we know, no work handles strategy for integrating new mobility concepts. A behavioral model study that includes a mixed choice set of privately owned vehicles, public transit, and the futuristic mobility concepts is needed, since this scenario is more likely to happen in the next decades than a future with only autonomous vehicles.

Today, there is an absence of an overall review across all studies on user preferences due to the topic's relatively new status. The deployment of new innovative mobility will differ in terms of adoption and ownership from one city to another. Empirical results in a study in a metropolitan area in the United States will probably not be valid for another metro area in Europe. Readers are referred to Surveys that are not restricted to a specific city are recommended (remove recommended) (Tennant, Stares, & Howard, 2019).

For brevity, this section focuses on modeling user preferences and their effect on policies and strategies. We focus more on modeling in the next sections. For analytical models, readers are referred to (van den Berg & Verhoef, 2016) among many. For a global overview of the challenges, opportunities, and barriers, we recommend (Fagnant & Kockelman, 2015).

7.4 Tactical Perspective

Tactical plans are created to fill a gap between existing long-term visions for urban mobility, strategies, and mobility systems' actual deployment. Naturally, this should be the second point to analyze after the strategy.

In the previous section we gained insights on the best deployment strategies and decision making processes for problems, such as the charging stations location, the fleet sizing, and integrating new mobility modes into an exisitng transport networks. In this section, we collect findings in the recent literature and put forward the best recommendations in tactics in deploying innovative mobility, assessing the gaps, and where the research should be oriented. We also consider research that uses agent-based simulations to emit recommendations on the tactical level. The literature in this aspect is rich and covers a wide range of issues.

Many approaches study the optimal deployment strategies of charging stations (Yıldız, Olcaytu, & Şen, 2019), the deployment of a single lane for autonomous vehicles to the use of game theory and market penetration strategies to penetrate the urban mobility network (Hatzenbühler, Cats, & Jenelius, 2020; Luo, Saigal, Chen, & Yin, 2019). These studies shed light on the factors to be considered and decisions to be made. The value of these approaches is to mitigate the adverse effects and impacts of new integrations, maximize usage, and reduce deployment costs. Tactical plans usually work on research to find the best solutions for safety concerns, infrastructure, integrated mobility, increase space efficiency, design smart networks, improve transportation system efficiency.

Many research studies focus on the sizing of AV fleets for on-demand services using agent-based simulation techniques. One work assesses the required fleet sizes to satisfy different demand levels for the greater Zurich region (Boesch, Ciari, & Axhausen, 2016). In a use case in Austin, Texas, a study shows that the sizing of a fleet of shared autonomous electric vehicles is sensitive to battery recharge time and vehicle range, while also studying different scenarios of charging infrastructures (Chen, Kockelman, & Hanna, 2016a; Loeb, Kockelman, & Liu, 2018). It is also suggested that properly sized fleets of shared on-demand taxis and minibuses can replace privately owned cars in Lisbon, Portugal (Martinez & Viegas, 2017).

In recent research we see a significant hypothetical shift in AV deployment with dynamic ride-sharing. There will be a considerable drop in necessary fleet sizes with the integration of new innovative mobility systems (Vosooghi, Kamel, Puchinger, Leblond, & Jankovic, 2019), (Vazifeh, Santi, Resta, Strogatz, & Ratti, 2018).

We see the second significant change is the drop of CO2 emissions thanks to clean energy, electrification of vehicles, and efficient operations. Global daily CO2 emissions will be reduced to 80% with the complete integration of fully electrical SAVs (Lokhandwala & Cai, 2020). Several studies have been made regarding the sustainability concerns raised by autonomous vehicles. Research shows how these studies are different and sheds light on some research gaps to be filled in future works (Williams, Das, & Fisher, 2020).

Research work is done for tactical plans to deploy new innovative mobility, such as line-based autonomous buses (ABs). The team studied the AB allocation problem and assessed changes in the service frequency and vehicle capacity settings. There is a general reduction of the total cost when deploying autonomous buses (Hatzenbühler et al., 2020). We refer the reader to Chap. 4 of the book.

Early deployment of automated vehicles (AVs) may likely cause losses (Luo et al., 2019). However, after there is a sufficient number of such vehicles in the traffic stream, many benefits can be realized, such as reducing the total cost (Hatzenbühler et al., 2020) and the CO2 emissions (Lokhandwala & Cai, 2020); the reader is referred to in Chap. 4 on the economic assessment.

In (Luo et al., 2019), the researchers used a dynamic game approach that considers the uncertainty in the market forecast such as subsidy policies to accelerate the deployment process, and the information asymmetry that may be caused by government agency's unawareness of the subsidized entity's actual effort in promoting AV, hence affecting the deployment plan. Also, Chen, He, Zhang, and Yin (2016b) presented a mathematical method for a deployment plan of AVs that can promote AVs adoption.

The tactics are extensive. Every tactical plan's complex structure makes it challenging to capture the interaction with other deployment optimization points and define clear conclusion points on the overall deployment plan.

In our view, the tactical plans should focus on mixed traffic scenarios and assess results by considering the existing modes that will not go away anytime soon. Tactical research papers lack a global overview of the situation.

Finally, the most significant change in infrastructure will be deploying new power grids and charging stations. A significant tactical challenge is the deployment plan for the whole infrastructure. Readers are encouraged to explore comprehensive studies that were made into this area like those from Iacobucci, McLellan, and Tezuka (2019) and Bösch, Becker, Becker, and Axhausen (2018), and for studies oriented to the cost of infrastructure cost of electric recharge stations, where a comprehensive estimation study of the recharge station infrastructure cost across U.S. Metropolitan areas from Nicholas (2019).

We have left out the discussion on charging stations on Electric and Autonomous vehicles' deployment pace despite this being an essential factor for the growth and acceleration of the public electric fleet adoption rate. For instance, if we have fast and available charging stations, this will lead to more capacity for a massive fleet and will increase the adoption rate, equally in the setting of home parking in the growth of ownership of EVs and E-AVs. For a study on the infrastructure of charging stations' impact on the market of EVs, we refer the reader to (Ou, Lin, He, Przesmitzki, & Bouchard, 2020).

7.5 Operational Perspective

A growing body of research characterizes and controls mobility's operational perspective for ensuring day-to-day operations. These researches range from demand estimation, routing optimization, shared mobility, and reducing operating costs.

Shared mobility concepts contain many variants and characteristics. A great visual representation of the problem's features is presented (Mourad, Puchinger, & Chu, 2019). In this chapter, we're interested in integrating the new innovative mobility with public transit problems.

Solutions, when it comes to modeling the integration of new mobility systems with existing ones in two subsets, are:

- **Simulation-based models:**

Simulation-based models that capture mobility systems with high fidelity and incorporate complex and microscopic interactions (Salazar et al., 2018).

- **Network flow models:**

Network flow models are amenable to efficient optimization and allow for various complex constraints (Salazar et al., 2018).

These solution approaches are valuable. They mitigate the adverse effects and impacts of new integrations, such as additional costs and waiting times, and improve service quality.

In multimodal commutes, we find integrating the innovative mobility modes in the first and last-mile problem settings. The objective is to minimize the response time to passenger requests while reducing vehicle operating costs by reducing the number of vehicles used to serve given passenger demands. Research findings affirm that with the integration of AV modes, the operational task will be more efficient (Salazar et al., 2018). This evolution will lead to the consideration of narrow time windows and eventually improve the quality of service.

To conclude, we identify a gap in the research work that mixes innovative mobility solutions and multimodal transport. However, this mixing exists in real life and will be the base of integrating new innovative mobility. There's an evident lack of research output in optimization problems when it comes to intermodal trip operations. Considerable research in this part is found in (Stiglic, Agatz, Savelsbergh, & Gradisar, 2018), where the possibility of realizing seamless integration of ride-sharing and public transit is investigated. As it offers fast, reliable, and affordable transfers to and from transit stations in suburban areas.

In the paper, they mentioned the ride-matching technologies that are required to make it a reality. They consider a centralized system that automatically establishes matches between drivers and riders and finally turns it into a matching rides problem. They evaluated the benefits of this integration by comparing instances of ride-matching with and without the ride-sharing service. Fahnenschreiber, Gündling, Keyhani, and Schnee (2016) worked on combining dynamic ride-sharing and public transport, they address two problems in multimodality; the first is to connect public transport stations with dynamic ride-sharing, and the second is connecting the start and destination of a query to public station routes by dynamic ride-sharing courses. However, their contribution to the subject is more on route planning. The paper proposes excellent ride-matching methods and finding connections; they also showed better connections using ride-sharing and two modes of transport in terms of travel duration and cost.

Other researchers studied the same public transport feeding challenge. Still, with autonomous mobility-on-demand in highly dense cities, not rural areas, they presented a network flow optimization model that captures the joint operations of autonomous mobility-on-demand systems and public transit (Salazar et al., 2018). Their results show that autonomous mobility-on-demand systems can significantly reduce travel times, pollutant emissions, the total number of cars, and overall costs compared to an autonomous mobility-on-demand system operating in isolation (Mendes, Bennàssar, & Chow, 2017). These findings are significant because we see shared mobility to improve public transport, but the reciprocity is also valid.

Diving into AV systems, a lot of research output exists. Levin, Odell, Samarasena, and Schwartz (2019) studied the link transmission model for traffic flow on transit and SAV integration to shorten travel time. Porru, Misso, Pani, and Repetto (2020) shed light on the challenges associated with smart mobility from a telematic point of view. Shen, Zhang, and Zhao (2018), examined the impact of repurposing low-demand bus routes and using SAVs as an alternative. Their results show that the integrated system can enhance service quality, occupying fewer road resources, being financially sustainable, and utilizing bus services more efficiently. From the users' point of view, (Hilgarter & Granig, 2020) explore the passenger's mobility behavior and their general attitude towards AV in mixed traffic settings (Zijlstra et al., 2020). They are studying innovative mobility in the context of MaaS. They have established indicators to identify early adopters: innovativeness, tech-savvy, needing travel information, having a multimodal mindset, and wanting freedom of choice.

Several types of research used agent-based simulation to study the operation of mobility services to increase their efficiency. For example, assignment strategies for on-demand autonomous vehicles are compared (Hyland & Mahmassani, 2018). They were considering a scenario with a fleet of AVs controlled by a central operator willing to minimize fleet miles and traveler wait times. Additionally, travel requests should be answered as they arrive dynamically from users that desire to travel immediately. This study compared six assignment strategies on a grid-based network and found that the optimization-based ones and en-route AVs to be diverted to new requests are more efficient than less sophisticated strategies.

Moreover, the difference is more noticeable when the fleet is highly used. A similar study was performed on Zurich's use case (Hörl, Ruch, Becker, Frazzoli, & Axhausen, 2019) by comparing four strategies, while also considering the rebalancing problem (where to send the AVs when they are idle to better respond to future demand). The simulation results showed that even though one strategy stands out as the best in waiting times, interesting differences are observed between the other strategies in different situations. A testbed and open-source framework for simulating autonomous mobility-on-demand with different fleet management policies has been developed and first described (Ruch, Horl, & Frazzoli, 2018). This framework is still in progress and currently implements more than ten algorithms. Giannakopoulou (2019) proposes an overview of the algorithmic approaches related to mobility systems' operation in general and for shared mobility in particular (Mourad et al., 2019).

To conclude this part, all the studies show that integrating innovative mobility systems with dynamic ride-sharing and a public transit system can significantly enhance mobility and increase public transport use, which is an expected result. With the introduction of autonomous mobility, this problem becomes less challenging. There seems to be a lack of algorithms efficiently integrating public transports with on-demand mobility systems.

There is a shift in societal behavior toward alternative transportation modes and green mobility patterns. From an operational point of view, we see that it is the richest part of numerous outputs. The research gaps identified are optimization models in mixed traffic scenarios and ride-matching between PT modes and AVs. However, we believe that the operational part is the most advanced since it is less in contact with the human factor and runs on the same operational concepts, and tackles the same classical optimization problems with additional attributes.

7.6 Innovative Mobility: Future of Integration

We explored the research effort on the deployment of new innovative mobility. From a global perspective, a world with innovative mobility solutions seems somewhat futuristic. There is some hypothetical bias driving these research efforts. Only once the large-scale AV deployment becomes a reality, the picture we have drawn based on research and simulation will evolve. The absence of an overall review across all studies on user preferences in integrating new innovative mobility shows the importance of conducting research to compare all these reviews and build a global analysis that will contribute to the evolution of this reasonably new subject.

Table 7.1 summarizes the main conclusions from the three perspectives discussed, strategic, tactical, and operational, along with the research gaps that we have identified.

A leap in technology might change our perspective on the future. Now we see AVs as a significant topic of interest as a complement to public transport. We might see advancements in other innovative modes that can change the way AVs will be deployed, such as Hyperloop technology.

As a result of the recent and ongoing COVID-19 pandemic, telecommunication systems are under the spotlight again. Teleworking has become the new normal in many different professional settings, and people working in those sectors are questioning the necessity of a daily commute. This situation shows that not only technological shifts and societal changes may affect mobility behavior but also external events such as health crises can have a significant impact. Significant external events such as the COVID-19 crisis also create opportunities to modify the transport system as we knew it (Budd & Ison, 2020).

Disruption in public transit is inevitable: travel habits evolve, fixed routes cannot keep up with growing populations, varying densities, different work habits (as an example, an aging population). Public transit, in its current setting and capacity, will need to evolve with these changes.

Table 7.1 Main conclusions and research gaps for each discussed perspective

Perspective	Main conclusions from the literature	Identified research gaps
Strategical	Services that use the existing infrastructure are more appealing to deploy. New mobility solutions are not guaranteed to be accepted by users as there may exist potential barriers.	A lack of studies interested in strategies to integrate new mobility concepts among existing ones. Absence of an overall review across all studies on user preferences.
Tactical	Tactical decisions such as the size of an AV fleet greatly influence the attractiveness of new mobility and thus the modal shifts of the users. Sustainability can benefit from the deployment of new mobility services based on EVs.	Tactical research papers lack a global overview that considers existing modes of transportation.
Operational	Simulation-based models and network flow models are both practical approaches to model new mobility systems. The operation strategy of a mobility service has a considerable impact on its efficiency.	A lack of algorithms efficiently integrating public transports with on-demand mobility systems. The algorithms should optimize models in mixed traffic scenarios and ride-matching schemes.

Some researchers believe that AV deployment can threaten PT (Krueger et al., 2016) if it offers more dynamic solutions, less wait time, and a competitive price. However, public transportation is the only mode that has the mandate to provide equitable mobility. Private companies don't have that mandate (Kumar, n.d.). Suppose we reach a point where AV-based transit can offer a reliable, fair, cheap service with the same capacity the classic PT offers. In that case, PT will have to transition to AV solutions, which will be the urban mobility ecosystem's natural evolution.

To deploy or integrate an innovative mobility solution, one must understand the riders and how they move to define their travel patterns (Tennant et al., 2019). We should also understand the amount of data we need to provide to have a seamless mobility experience. Innovative mobility solutions are already facing troubles when it comes to data ownership, protection, and governance. Some governments require to access the population mobility data (Walsh, 2017), companies trying to integrate new innovative mobility services into existing ones are always faced with a higher rate of criticism. A single mistake can lead a whole project to be suspended (Conger, 2020).

Although AVs everywhere will not be a reality soon, local authorities are planning and raising questions. We are witnessing changes and integration experiments happening today. However, there are many uncertainties regarding the long-term impacts of integrating autonomous mobility in public transit systems that need to be explored in the future.

Acknowledgments This research work has been carried out in the framework of the Technological Research Institute SystemX and therefore granted with public funds within the scope of the French Program "Investissements d'Avenir."

References

Alyavina, E., Nikitas, A., & Tchouamou Njoya, E. (2020). Mobility as a service and sustainable travel behavior: A thematic analysis study. *Transportation Research Part F: Traffic Psychology and Behaviour, 73*, 362–381. https://doi.org/10.1016/j.trf.2020.07.004

Arias-Molinares, D., & García-Palomares, J. C. (2020). The Ws of MaaS: Understanding mobility as a service from the literature review. *IATSS Research*. https://doi.org/10.1016/j.iatssr.2020.02.001.

van den Berg, V. A. C., & Verhoef, E. T. (2016). Autonomous cars and dynamic bottleneck congestion: The effects on capacity, the value of time, and preference heterogeneity. *Transportation Research. Part B: Methodological, 94*(December), 43–60. https://doi.org/10.1016/j.trb.2016.08.018

Boesch, P. M., Ciari, F., & Axhausen, K. W. (2016). Autonomous vehicle Fleet sizes required to serve different levels of demand. *Transportation Research Record: Journal of the Transportation Research Board, 2542*(1), 111–119. https://doi.org/10.3141/2542-13

Bösch, P. M., Becker, F., Becker, H., & Axhausen, K. W. (2018). Cost-based analysis of autonomous mobility services. *Transport Policy, 64*, 76–91. https://doi.org/10.1016/j.tranpol.2017.09.005

Budd, L., & Ison, S. (2020). Responsible transport: A post-COVID agenda for transport policy and practice. *Transportation Research Interdisciplinary Perspectives, 6*, 100151. https://doi.org/10.1016/j.trip.2020.100151

Chen, T. D., Kockelman, K. M., & Hanna, J. P. (2016a). Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. *Transportation Research Part A: Policy and Practice, 94*, 243–254. https://doi.org/10.1016/j.tra.2016.08.020

Chen, Z., He, F., Zhang, L., & Yin, Y. (2016b). Optimal deployment of autonomous vehicle lanes with endogenous market penetration. *Transportation Research Part C: Emerging Technologies, 72*, 143–156. https://doi.org/10.1016/j.trc.2016.09.013

Conger, K. (2020, Septembre 15). Driver charged in Uber's fatal 2018 autonomous Car crash. *The New York Times*. https://www.nytimes.com/2020/09/15/technology/uber-autonomous-crash-driver-charged.html. Consulté le 9 janvier 2021.

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers, and policy recommendations. *Transportation Research Part A: Policy and Practice, 77*, 167–181. https://doi.org/10.1016/j.tra.2015.04.003

Fahnenschreiber, S., Gündling, F., Keyhani, M. H., & Schnee, M. (2016). A multi-modal routing approach combining dynamic ride-sharing and public transport. *Transportation Research Procedia, 13*, 176–183. https://doi.org/10.1016/j.trpro.2016.05.018

Giannakopoulou, K. (2019). Algorithms for cloud-based smart mobility. In Y. Disser & V. S. Verykios (Éd.), Algorithmic aspects of cloud computing (p. 152–168). Cham: Springer. https://doi.org/10.1007/978-3-030-19759-9_10.

Hatzenbühler, J., Cats, O., & Jenelius, E. (2020). Transitioning towards the deployment of line-based autonomous buses: Consequences for service frequency and vehicle capacity. *Transportation Research Part A: Policy and Practice, 138*, 491–507. https://doi.org/10.1016/j.tra.2020.06.019

Hilgarter, K., & Granig, P. (2020). Public perception of autonomous vehicles: A qualitative study based on interviews after riding an autonomous shuttle. *Transportation Research Part F: Traffic Psychology and Behaviour, 72*, 226–243. https://doi.org/10.1016/j.trf.2020.05.012

Hörl, S., Ruch, C., Becker, F., Frazzoli, E., & Axhausen, K. W. (2019). Fleet operational policies for automated mobility: A simulation assessment for Zurich. *Transportation Research Part C: Emerging Technologies, 102*, 20–31. https://doi.org/10.1016/j.trc.2019.02.020

Hyland, M., & Mahmassani, H. S. (2018). Dynamic autonomous vehicle fleet operations: Optimization-based strategies to assign AVs to immediate traveler demand requests. *Transportation Research Part C: Emerging Technologies, 92*, 278–297. https://doi.org/10.1016/j.trc.2018.05.003

Iacobucci, R., McLellan, B., & Tezuka, T. (2019). Costs and carbon emissions of shared autonomous electric vehicles in a virtual power plant and microgrid with renewable energy. *Energy Procedia, 156*, 401–405. https://doi.org/10.1016/j.egypro.2018.11.104

(J3163) SAE, M. (2018). J3163: Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies - SAE International. https://www.sae.org/standards/content/j3163_201809/. Consulté le 6 décembre 2020.

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation Research Part C: Emerging Technologies, 69*, 343–355. https://doi.org/10.1016/j.trc.2016.06.015

Kumar, R. (n.d.). *Transport Innovation Online Summit 2020*. https://app.swapcard.com/event/transport-innovation-online-summit-2020/planning/UGxhbm5pbmdfMTQ3Njcw. Consulté le 16 novembre 2020.

Levin, M. W., Odell, M., Samarasena, S., & Schwartz, A. (2019). A linear program for optimal integration of shared autonomous vehicles with public transit. *Transportation Research Part C: Emerging Technologies, 109*, 267–288. https://doi.org/10.1016/j.trc.2019.10.007

Loeb, B., Kockelman, K. M., & Liu, J. (2018). Shared autonomous electric vehicle (SAEV) operations across the Austin, Texas network with charging infrastructure decisions. *Transportation Research Part C: Emerging Technologies, 89*, 222–233. https://doi.org/10.1016/j.trc.2018.01.019

Lokhandwala, M., & Cai, H. (2020). Siting charging stations for electric vehicle adoption in shared autonomous fleets. *Transportation Research Part D: Transport and Environment, 80*, 102231. https://doi.org/10.1016/j.trd.2020.102231

Luo, Q., Saigal, R., Chen, Z., & Yin, Y. (2019). Accelerating the adoption of automated vehicles by subsidies: A dynamic games approach. *Transportation Research Part B: Methodological, 129*, 226–243. https://doi.org/10.1016/j.trb.2019.09.011

Nilles, J. M. (1978). The telecommunications-transportation tradeoff: Options for tomorrow: Jack M. Nilles, F. Roy Carlson, Jr., Paul Gray, and Gerhard J. Hanneman, Wiley-Interscience, John Wiley & Sons, New York, 1976, 196 pp., $22.95. *Technological Forecasting and Social Change*, *11*(2), 187. https://doi.org/10.1016/0040-1625(78)90029-X.

Martinez, L. M., & Viegas, J. M. (2017). Assessing the impacts of deploying a shared self-driving urban mobility system: An agent-based model applied to the city of Lisbon, Portugal. *International Journal of Transportation Science and Technology, 6*(1), 13–27. https://doi.org/10.1016/j.ijtst.2017.05.005

Mendes, L. M., Bennàssar, M. R., & Chow, J. Y. J. (2017). Comparison of light rail streetcar against shared autonomous vehicle Fleet for Brooklyn–Queens connector in New York City: *Transportation Research Record*. https://doi.org/10.3141/2650-17.

Mourad, A., Puchinger, J., & Chu, C. (2019). A survey of models and algorithms for optimizing shared mobility. *Transportation Research Part B: Methodological, 123*, 323–346. https://doi.org/10.1016/j.trb.2019.02.003

Nazari, F., Noruzoliaee, M., & Mohammadian, A. (2018). Shared Mobility Versus Private Car Ownership: a Multivariate Analysis of Public Interest in Autonomous Vehicles. Présenté à Transportation Research Board 97th Annual MeetingTransportation Research Board. https://trid.trb.org/view/1496172. Consulté le 13 November 2020.

Nicholas, M. (2019). Estimating electric vehicle charging infrastructure costs across majorU.S. metropolitan areas, 11.

Olson, M. (1971). The logic of collective action — Mancur Olson, Jr. https://www.hup.harvard.edu/catalog.php?isbn=9780674537514. Consulté le 6 décembre 2020.

Ou, S., Lin, Z., He, X., Przesmitzki, S., & Bouchard, J. (2020). Modeling charging infrastructure impact on the electric vehicle market in China. *Transportation Research Part D: Transport and Environment, 81*, 102248. https://doi.org/10.1016/j.trd.2020.102248

Porru, S., Misso, F. E., Pani, F. E., & Repetto, C. (2020). Smart mobility and public transport: Opportunities and challenges in rural and urban areas. *Journal of Traffic and Transportation Engineering (English Edition), 7*(1), 88–97. https://doi.org/10.1016/j.jtte.2019.10.002

Ruch, C., Horl, S., & Frazzoli, E. (2018). AMoDeus, a simulation-based testbed for autonomous mobility-on-demand systems. In *The 2018 21st International Conference on Intelligent Transportation Systems (ITSC)* (pp. 3639–3644). Maui, HI: IEEE. https://doi.org/10.1109/ITSC.2018.8569961

Salazar, M., Rossi, F., Schiffer, M., Onder, C. H., & Pavone, M. (2018). On the interaction between autonomous mobility-on-demand and public transportation systems. *arXiv:1804.11278 [cs]*. http://arxiv.org/abs/1804.11278. Consulté le 15 October 2020.

Shen, Y., Zhang, H., & Zhao, J. (2018). Integrating shared autonomous vehicles in the public transportation system: A supply-side simulation of the first-mile service in Singapore. *Transportation Research Part A: Policy and Practice, 113*, 125–136. https://doi.org/10.1016/j.tra.2018.04.004

Sieber, L., Ruch, C., Hörl, S., Axhausen, K. W., & Frazzoli, E. (2020). Improved public transportation in rural areas with self-driving cars: A study on the operation of Swiss train lines. *Transportation Research Part A: Policy and Practice, 134*, 35–51. https://doi.org/10.1016/j.tra.2020.01.020

Stiglic, M., Agatz, N., Savelsbergh, M., & Gradisar, M. (2018). Enhancing urban mobility: Integrating ride-sharing and public transit. *Computers & Operations Research, 90*, 12–21. https://doi.org/10.1016/j.cor.2017.08.016

Tennant, C., Stares, S., & Howard, S. (2019). Public discomfort at the prospect of autonomous vehicles: Building on previous surveys to measure attitudes in 11 countries. *Transportation Research Part F: Traffic Psychology and Behaviour, 64*, 98–118. https://doi.org/10.1016/j.trf.2019.04.017

Transportation Research Board, & National Academies of Sciences, E., and Medicine. (2012). *Ridesharing as a complement to transit*. Washington, DC: The National Academies Press. https://doi.org/10.17226/14655

Vazifeh, M. M., Santi, P., Resta, G., Strogatz, S. H., & Ratti, C. (2018). Addressing the minimum fleet problem in on-demand urban mobility. *Nature, 557*(7706), 534–538. https://doi.org/10.1038/s41586-018-0095-1

Vosooghi, R., Kamel, J., Puchinger, J., Leblond, V., & Jankovic, M. (2019). Robo-taxi service Fleet sizing: Assessing the impact of user trust and willingness to use. In *98th Annual Meeting of the Transportation Research Board*. Washington, DC., United States. https://hal.archives-ouvertes.fr/hal-01940330. Consulté le 13 November 2020.

Walsh, D. (2017, Juin 10). The dilemma for Uber and rival: Egypt's demand for data on riders (Published 2017). *The New York Times*. https://www.nytimes.com/2017/06/10/world/middleeast/egypt-uber-sisi-surveillance-repression-careem.html. Consulté le 9 Janvier 2021.

Williams, E., Das, V., & Fisher, A. (2020). Assessing the sustainability implications of autonomous vehicles: Recommendations for research community practice. *Sustainability, 12*(5). https://doi.org/10.3390/su12051902

Yıldız, B., Olcaytu, E., & Şen, A. (2019). The urban recharging infrastructure design problem with stochastic demands and capacitated charging stations. *Transportation Research Part B: Methodological, 119*, 22–44. https://doi.org/10.1016/j.trb.2018.11.001

Zijlstra, T., Durand, A., Hoogendoorn-Lanser, S., & Harms, L. (2020). Early adopters of mobility-as-a-Service in the Netherlands. *Transport Policy, 97*, 197–209. https://doi.org/10.1016/j.tranpol.2020.07.019

Chapter 8
Public Transport in Emerging Countries: From Old Dilemmas to Opportunities for Transition to Sustainable Mobility Through the Case of Brazil

Adriana Marotti De Mello, João Valsecchi Ribeiro De Souza, and Roberto Marx

Abstract Throughout their trajectory, emerging countries like Brazil have not prioritized alternatives that guarantee the sustainable development of its public transport system, accumulating relevant gaps in infrastructure, quality and access to public transport. In this sense, the objective of this chapter is to present the context in which public transport has been developing in Brazil, both historically and currently, discussing the dilemmas and opportunities that could enable the transition to a more sustainable public transport system in the country. It seems that innovation projects based on sustainability in ubiquitous mobility are very welcome, but they do not replace the need for a conventional public transport solution. Additionally, automakers will not lead the most relevant transformations since most of the initiatives aimed at contributing to reduce the gaps from the public transport in Brazil come from new players interested in developing business models in this field, especially nascent companies focused on implementation of new technologies for the provision of mobility services. Although no new single player will be able to cause systemic changes alone, some opportunities are presented in order to improve the discussion about the development of a more sustainable public transport in the country, as well as to contribute as a reference for other emerging countries that may face similar challenges.

Keywords Public transport · Sustainable mobility · Brazil

A. Marotti De Mello (✉)
School of Economics, Business and Accounting, University of São Paulo, São Paulo, Brazil
e-mail: adriana.marotti@usp.br

J. Valsecchi Ribeiro De Souza · R. Marx
Polytechnic School, Production Engineering Department, University of São Paulo, São Paulo, Brazil
e-mail: joao.valsecchi.souza@usp.br; robemarx@usp.br

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_8

8.1 Public Transport in Brazil: Context, Dilemmas and Covid-19

During the last decades, investments in transportation and infrastructure in Brazil have focused on the effort to expand the space dedicated to automobiles, contributing to the growth of the motorization of individual modes of use (cars, bicycles, taxis, etc.), which between the 2000s and 2010 increased by 45%.[1] The use of private motorized vehicles brings gains in comfort and ease of travel, but there are many negative and well established impacts. In large cities, the emission of pollutants, road accidents and congestion are increasing as the population opts for private transport to the detriment of public transport. Adequate infrastructure is vital for public bus transportation to avoid the tendency to suffer substantial drop in operational speed, in the comfort of its users and in the reliability of travel times in Brazil.

According to a survey in nine Brazilian capitals regarding public transport demand carried out by NTU (2017),[2] between 2014 and 2015, there was an average decrease in the daily demand of three million paying passengers, causing a 9% reduction in demand. Between 1993 and 2017, the passenger rate per kilometer fell by more than 35% or 2% per year (2019).[3] An important cause for the loss of passengers was the quality offered by the public transport service, considered low or very low by 57% of the Brazilian population (2011).[4] Allied to this, there was, in many periods, the tax exemption for the purchase of automobiles, resulting from the policies of the federal government, which tends to increase even more the current 31% share of private motor vehicles in the urban modal split (2017).[5]

With buses increasingly stuck in congestion and the population in need of more attention to mobility, it is necessary to conclude that the population in Brazil prioritizes the culture of the private vehicle.

The traffic on the streets is not only made by vehicles (motorized or not), but also by active mobility with people circulating on sidewalks and roads. About 36% of Brazilians travel exclusively on foot daily, while 41% complete their trips significantly on foot (data from 2017).[6] This number has risen over the past few years, as a result of the economic crisis, increased tariffs and lack of comfort offered by public transport operators (PTOs).

---

[1] https://www.gov.br/infraestrutura/pt-br/assuntos/transito/conteudo-denatran/estatisticas-frota-de-veiculos-denatran

[2] https://www.ntu.org.br/novo/upload/Publicacao/Pub636391736883773822.pdf

[3] http://files.antp.org.br/2019/7/2/construindo-o-amanha_web_erratas.pdf

[4] http://arquivos.portaldaindustria.com.br/app/conteudo_24/2012/07/09/78/20120828020523780956i.pdf

[5] http://files.antp.org.br/simob/sistema-de-informacao-de-mobilidade-urbana-da-antp%2D%2D2017.pdf

[6] http://files.antp.org.br/simob/sistema-de-informacao-de-mobilidade-urbana-da-antp%2D%2D2017.pdf

On the other hand, active mobility is one of the fundamental elements of sustainable urban development: cities suitable for walking are more equitable and contribute to the health and safety of their inhabitants. Walking is a democratic and healthy way of getting around. The debate around the quality of life in contemporary cities and the importance of thinking and planning the urban space for pedestrians is one of the most relevant on the global agenda today, present in the UN Sustainable Development Goals (SDGs) and in the New Urban Agenda, declared in Habitat III. However, very little has been done in Brazil to facilitate active mobility as a comfortable alternative for the citizens.

Furthermore, in recent years, new business models have emerged as an alternative to traditional modes and the bicycle – in itself a very old one – has seen a revival of its use, particularly in the younger and middle-class and high medium. The search for individual commuting options boosted adherence to bicycle use, with a record increase of 118% in sales of this equipment between July 2019 and July 2020, according to data from the Brazilian Association of the Bicycle Sector.[7]

An extreme situation like the Covid-19 pandemic sheds light on the way in which cities and urban mobility in particular are organized and can play a relevant role in bringing about change, depending on how this situation is handled. Urban public transport systems, which for decades have been largely structured and operated by private capital, have shown their fragility as an essential public service.

With the arrival of the pandemic, the loss of bus companies in Brazil should reach, by the end of December 2020, R$ 8.7 billion. The estimate, from the National Association of Urban Transport Companies (NTU), reveals a system that operates with 42% less demand than prior to the pandemic, which anticipates the potential for the even greater crisis than expected in early 2021, when the newly elected mayors take office and the deadline for tariff readjustments in most major cities expire.

The bus fare subsidy, adopted in 74% of European Union countries, ranging from 26% (Prague) to 54% (Amsterdam), is something rarely observed in cities in Brazil. The highest level is in São Paulo (38%). In Florianópolis, the tariff is subsidized at 21% of the value, in Vitória and Curitiba, respectively, at 16% and 14%. The contribution of the São Paulo treasury means that the ticket, which should be fixed at R $7.12, is R$ 4.40.[8]

The fact is that in Brazil, differently from what happened in many other countries in the world, very little has been done to enable the use of public transport in more appropriate conditions to stop the spread of the virus. Such treatment is due to the reduced influence or even guidance of the public authorities and urban mobility authorities in Brazil in dealing with issues that affect the health and comfort of the citizen in the use of public transportation. As a result, the part of the population that had a choice, switched from public to individual transport, while a large portion of

[7] https://aliancabike.org.br/dados-do-setor/#

[8] https://valor.globo.com/eu-e/coluna/maria-cristina-fernandes-a-bomba-contratada-da-tarifa-de-onibus.ghtml

the population continues to use public transport, which is often crowded and with no compliance on sanitary measures associated with the prevention of Covid-19.

Living conditions on the outskirts of the large urban centers, the non-universalization of sanitation, economic inequality and precarious transport have their consequences: they contribute to the impacts of the new coronavirus being greater and more severe among the poorest population.

Public transport users face increasingly worse services: crowded and poorly maintained vehicles, high prices, reduced hours. A FGV/DAPP (2014)[9] survey already pointed to the alarming numbers of dissatisfaction with the service in Brazil: 73% of passengers were dissatisfied or very dissatisfied with public transport in Brazilian metropolitan regions. This number reached 77% in Rio de Janeiro and 82% in Brasília.

With the pandemic, all of this has intensified. The sharp decrease in passenger number during the quarantine caused revenue to decrease. The answer, in practically all major Brazilian cities, was the suspension of lines and services, reduction of fleets, closure of stations and operational adjustments with increased service intervals. In several cities, maximum capacity protocols for buses and trains were created, but the reduced inspection did not guarantee the effectiveness of these actions. The conflict between public interests – quality, comfort, supply – and those related to the form of financing was made explicit.

There are plenty of examples worldwide treating public transport as an essential service, including as part of Covid-19's containment strategies in urban centers. In the US, the Coronavirus Aid, Relief and Economic Security Act (2020),[10] a $ 2 trillion emergency package, released in late March 2020, earmarked $ 25 billion for public transportation agencies to ensure maintenance service and jobs in the sector.

In several countries, cities have demonstrated that the adequacy of the network to guarantee the provision of the service safely is feasible. The review of the operation to ensure access to health care for professionals and patients, for example, was carried out in Madrid, Paris and Brussels, with an increase in supply or the creation of special services for access to hospitals and health equipment.

There is a possibility, raised in some studies, that the telework could transform the demand for transportation in urban centers. IPEA[11] (2020) forecasts point to the possibility of remote work in 25% of occupations in the labor market. However, this means that at least 75% of jobs, when resumed, will still rely on urban mobility systems for their daily commuting. These jobs are mostly located at the base of the economic pyramid, where there is a higher percentage of public transport usage.

A recent study published by IDB points out that "*in Brazil, and in other Latin American countries, a large part of the population uses public transportation as their only means of commuting to work during the pandemic*" (IDB, 2020). The

[9] http://dapp.fgv.br/wp-content/uploads/2016/11/DAPP-Estudos_Mobilidade-1.pdf

[10] https://home.treasury.gov/policy-issues/cares

[11] https://www.ipea.gov.br/cartadeconjuntura/index.php/2020/12/o-trabalho-remoto-e-a-pandemia-a-manutencao-do-status-quo-de-desigualdade-de-renda-no-pais/

equation here is not difficult to understand: the middle and upper classes of the population are protected while traveling in their private automobiles, while the lower classes assume the risk of traveling in poorly maintained public transport.

Considering that people are increasing their level of demand in relation to the service due to the greater offer of modes of commuting in cities (ex.: ride-hailing, bike-sharing, etc.), it is necessary to think about urban public transport within a logic of integrated management of modes and infrastructure. In this process, new technologies, especially applications for use via cell phones, electric motorization and new ways of integrating modes with an emphasis on the last-mile issues have a relevant role to play in this process.

8.2 The Role of Automakers in the Transition to Sustainable Mobility: From the Point of View of Solutions for Public Transport

Transition to a sustainable mobility system is a complex process and does not simply "occur": transition is the result of pressures from society and the growth and consolidation of niche innovations and experiments, where the role of coalitions formed during the transition are fundamental. No actor in the current regime, alone, would have sufficient resources (i.e., knowledge, capital, legitimacy, organization or leadership) to make this transition happen (Loorbach, 2010; Roberts et al., 2018). But in the case of mobility, the role of the automotive industry is key to this transition.

Several studies (Dijk, Orsato, & Kemp, 2013; Marx, Mello, Zilbovicius, & Lara, 2015; Orsato, Dijk, Kemp, & Yarime, 2011; Roberts et al., 2018) show that the automotive industry would be powerful enough, on a global scale, to positively or negatively impact policies related to the development of sustainable mobility systems, especially in countries where this industry is relevant to the Gross Domestic Product.

Institutional theory shows that actors can act together and contribute to institutional change. Sarasini and Jacob (2014) showed how the Swedish electric sector has been acting in relation to regulatory changes linked to the reduction of CO2 emissions. They argue that managers of companies in the sector act in the future and demonstrate considerable agency, in which they actively deliberate on a variety of structures received before responding to the incentives placed by public policies. In other words, they seem to support a very particular type of arrangement between government and industry, linked to what the authors called "institutional maintenance" – they choose a way to follow one policy, deliberately excluding others, always looking to maintain their structures and current operating models.

Berggren, Magnusson, and Sushandoyo (2015), in a study on sustainable innovation in the truck and bus industry, demonstrated that the role of the incumbent companies (the automakers, in this case) can be more complex than just resistance to change. The authors showed that automakers in the sector act simultaneously in incremental regime innovations and more radical niche innovations. They conclude that the role of the incumbent companies would be more active than that described by the multilevel perspective (see Geels & Schot, 2007) – and those companies would complement the current regime with transition technologies, that is, maintaining a certain technological trajectory that would also contribute to guide innovations at the niche level. Berggren et al. (2015) conclude by suggesting more research on how transitions occur at the company level with an analytical framework that goes beyond the niche-regime dichotomy, based on the understanding that companies will interact with policies to transition from niches to regimes and that their role is relevant at different levels.

The article by Dijk, Orsato, & Kemp (2013), as well as that by Berggren, Magnusson, and Sushandoyo (2015), show that the interaction between niche and regime is more complex than that described by Geels and Schot (2007). They argue that the emergence of electric vehicles, as a niche, changes the regime itself. In a transition model called by the authors "fit-stretch", it shows that electric motorization can be just a replacement of the current motorization, maintaining the same product architecture and business model (in a technological substitution, but not a transition), or it could change the configuration of the current transport system, if it is combined with other innovations in transport, in a process similar to the reconfiguration of Geels and Schot (2007).

Therefore, it is fundamental to understand how the automotive industry is incorporating the technological transformations connected to public transportation and mobility. In the next section, we discuss the case of public transport innovations in Brazil, especially in the city of São Paulo.

8.2.1 Innovations in Public Transport – BRT as a Solution for Large Brazilian Cities and the Difficulties in Implementing More Sustainable Technologies

In the last decade, motivated by major events such as the 2014 World Cup and the Rio de Janeiro Olympic Games, and by the federal government's works incentive program at the time (PAC – Programa de Aceleração de Crescimento - namely Growth Acceleration Program), which involved public-private partnerships for infrastructure development in the country) there was a strong demand for mobility projects in large Brazilian cities.[12]

[12] Despite the volume of investments made, many works were halted due to the political/economic crisis and legal problems faced by contractors, due to corruption charges. See the case of line 17 of the São Paulo subway. Its completion, scheduled for 2014, has been postponed to 2021 (https://www.metrocptm.com.br/estacao-morumbi-da-linha-17-ouro-tem-conclusao-adiada-para-marco-de-2021/).

In the city of São Paulo, investments were made in expanding the subway network and building exclusive bus corridors. In other capitals, such as Rio de Janeiro and Belo Horizonte, there were strong investments in the so-called BRT (Bus Rapid Transit).

BRT is a bus system that provides segregated infrastructure and traffic priority to buses, in order to improve speed and to deliver a better quality of service, with rapid stops. It is compared to a "metro on wheels" service, with the advantages of metro systems at lower costs. It was created in Curitiba (Brazil) in the 1980s (known as "tubular"). This business model was exported, through automakers and transport operators, to many other cities, such as Bogotá (Colombia), Mexico City, Istanbul (Turkey) and Brisbane (Australia) (Wright, 2011).

BRT was the big bet of automakers installed in Brazil (especially Volkswagen and Daimler) in innovation in public transport. Both companies, in addition to manufacturing buses, also supported the development of the project to implement the necessary infrastructure for their operation. In the city of Belo Horizonte, for example, VW was selected to supply buses for the BRT system and also assisted in the design of the required infrastructure.

Although BRT brings advantages in terms of comfort for users, reducing travel time, there was no guideline in the regulation of projects regarding the environmental impact of buses – they continued to use models with diesel engines, with no concern for reducing emissions. In a survey conducted with VW and Daimler (Marx et al., 2015), companies agree that in Europe there is greater control over cities and other regulatory bodies regarding vehicle design and operation specifications. In Brazil, especially in small cities, there is little regulatory power in cities, and therefore, few innovations and low quality requirements. The city of São Paulo, due to its importance in terms of market volume, ends up serving as a reference for other cities in Latin America in terms of its policies and regulations in public transport.

8.2.2 Electrical/Hybrid Buses in São Paulo – Barriers to Implementation of Cleaner Technologies

As an example of the difficulty in introducing cleaner technologies in public transport, this section describes the case of buses in the city of São Paulo. The bus fleet in the city of São Paulo is composed of about 12,000 vehicles, of which only approximately 250 are trolleybuses.[13] The rest are diesel-powered buses with mostly Euro V engines. Buses are the main form of transport used by the population in their trips, and also the main cause of air pollution in the city of São Paulo.

[13] http://www.sptrans.com.br/sptrans/

In 2009, São Paulo City approved its Climate Change Policy (Lei 14.933/2009),[14] which determines:

– Use of transport modes with less polluting potential and emission of greenhouse gases, with emphasis on the rail, subway, trolleybus network, and other means of transport using renewable fuels
– Establishment of limits and targets for progressive reduction and promotion of monitoring of greenhouse gas emissions for the Municipality's transportation system

But only in 2018, nine years after the Climate Change policy was approved, that the Council of São Paulo City approved law nr. 16,802, which establishes that vehicles that serve public transport must reduce carbon dioxide (CO2) emissions by 50% within 10 years and 100% in 20 years. The emission of particulate matter (PM) should drop by 90% and 95%, respectively, and the emission of nitrogen oxide (NOx) needs to be reduced by 80% and 95%. These numbers mean, in practice, the banning of diesel engines. Since 2013, however, the city of São Paulo did not have a long-term contract for the concession of bus lines to the city, and only after several discussions in the Chamber and in Justice, law 16.802 was introduced in the bidding process – the bus operators and automakers were against including these limits in the concession of services in the city.

Only in September 2019, the city of São Paulo started a pilot project to test 15 electric buses manufactured in Campinas by the Chinese company BYD. Daimler, back in 2014, had a project to manufacture hybrid buses, in partnership with the Brazilian Eletra, a trolleybus manufacturer. But to date, there is no large scale adoption of hybrid or Electric buses in any major city in Brazil.

The role of automakers and transportation companies was decisive for the law to have this extended period for replacing polluting buses through industry lobby – companies that operate transport claim higher costs of implementation – electric/hybrid buses have a higher acquisition cost than diesel powered. In the initial city hall proposal, the deadline was half that approved.

In summary: while cities like Shanghai (which has a fleet of buses similar to that of São Paulo) and London already established 100% use of hybrid or electric buses, the city of São Paulo will still be 20 years behind to fully implement a more sustainable bus fleet. The main automakers installed in Brazil have electric/hybrid and even hydrogen bus projects in other countries, but do not bring more advanced products to the Brazilian market, claiming "lack of competitiveness" and "higher costs". As local regulations do not induce the use of cleaner technologies – as in many other places in the world – companies in the sector are betting on the Brazilian market to continue to produce buses with diesel technology, especially in a scenario where the use of the diesel engine on buses, trucks and automobiles has been facing severe

[14] https://leismunicipais.com.br/a/sp/s/sao-paulo/lei-ordinaria/2009/1493/14933/lei-ordinaria-n-14933-2009-institui-a-politica-de-mudanca-do-clima-no-municipio-de-sao-paulo

restrictions – cities like London and Paris have legislation to ban the use of this type of engine in the next decade.

Meanwhile, automakers located in Brazil are trying to halt the implementation of Proconve 8, a vehicle emission reduction program, which determines the mandatory sale of diesel vehicles with EuroVI emission standards for 2023, claiming that this implementation would raise manufacturing costs.[15] This fact, as well as the difficulty of implementing the law 16.802 in São Paulo, show that, in the absence of effective action by public authorities and pressure from society, there are no significant advances in terms of the adoption of cleaner technologies by automakers (see Chapter 3 for legislation issues and Chapter 10 for further information on governance).

Although they already have ready-to-market solutions in their project portfolio that could improve air quality in cities, in the absence of effective pressure and legislation, they will not bring these solutions to the country.

This case described above demonstrates the role of companies in the automotive sector, acting as active agents in regimes and niches, as already discussed by Dijk et al. (2013) and Berggren et al. (2015). The automotive industry has the role of not only be shaped by, but also it influences the institutions that constitute a socio-technical regime.

This role of the industry also helps to corroborate Freyssenet's (2009) conclusions: contrary to what some of the literature discusses, it cannot be said that there is a single global strategy for automakers (even if they act globally), since different institutional contexts cause different strategies to be adopted in different organizational arrangements. This explains why there are different solutions and business models for mobility in different regimes. But with a common characteristic: the maintenance of the current mobility regime, within the possibilities.

The most radical transformation of the mobility regime, if it occurs, will not be due to the performance of the automotive industry, but by the action of other players such as the creation of stricter legislation, or the diffusion of innovations coming from the IT industry and the niches created by startups.

8.3 The Role of New Mobility Service Providers in the Transition to Sustainable Mobility in Brazil: Barriers and Drivers for the Business Models Implementation

In view of the challenges presented for the evolution of public transport in large urban centers in emerging countries, such as Brazil, we highlight some initiatives that have been developed in order to implement innovative business models that

[15] Source: https://diariodotransporte.com.br/2020/10/05/adiamento-do-proconve-pode-lancar-na-atmosfera-ate-20-a-mais-de-poluentes-diz-iema/ Acess in?

translate into services aimed at facilitating and improving access conditions of public transport by the population and addressing the role in generating value for its users, as well as some barriers and drivers faced by companies when implementing these new services.

In order to identify contributing opportunities for public transport from the business model perspective, aligned with the idea of sustainable urban mobility, we are based on the framework proposed by Souza, Mello and Marx (2019).

The first initiative refers to a platform for integrating tariff payments through digital technologies. In this sense, we highlight the case of a Brazilian startup – currently already operating in the market and referenced here with the fictitious name of "INTEGRA".

INTEGRA presents a digital payment management service for public transport fares and it is an important preliminary step towards MaaS (Mobility-as-a-Service). Through a free mobile application, public transport users make online credit recharges that can be used in any modal that is integrated into the platform system. The payment of tariffs, in turn, is made through physical approximation of the user's mobile device to the charging equipment that is installed in the vehicles, using Near Field Communication (NFC) technology.

The main aspects of generating value in the INTEGRA business model are encouraging the integration of public transport systems, as well as improving the conditions for the use of this type of transport and facilitating the creation of policies oriented to promote intermodal integration.

The substantial difference of this service in relation to an integrated public transport card – most common solution adopted by the public transport systems in cities – is that it allows multiple transport systems to be integrated into the platform. Therefore, it is possible that public and private transport systems from different cities are added to the same platform, eliminating the need for the user to have to pay more than once for intercity commuting, allowing greater convenience and ease for the user to access the public transport service and intermodality solutions.

The feasibility and availability of the service directly depend on agreements with the transport sector of the municipalities. The service users become holders of a digital wallet that can be used even for the payment of complementary services to public transport.

The second initiative refers to the well-known platforms offering information on public transport to the end user through a mobile application. Among the services offered, the following stand out: the actual time for bus in each stop, consultation of itineraries, channels for sharing relevant information about public transport, routing of origin and destination, recharge of electronic bus tickets, in addition to accessibility resources to disabled people.

The company, referred here with the fictitious name "BUS", recently expanded its proposal and today the application works as a platform to provide information of public utility about the different services of the cities to its citizens.

The application today integrates public transport information databases from several cities in Brazil, including the city of São Paulo, from open data policies or even information from databases that the company itself manages regarding its other fleet management products for bus operators.

BUS gathers in its database, based on the historical data of users, information such as: users' opinions regarding the quality of transport, the volume of demands for displacement of origin and destination and registration of occurrences in public transport. Some municipalities are already acquiring from BUS and using this kind of data to create, for example, public security policies and to plan and review the public transport network.

In addition, the platform is being used to add useful services to its users. An example of this is the disclosure of personalized job vacancies, so that users can access job vacancies close to their place of frequent origin, reducing the commute time or even the travel demand, aligned with the idea of decentralization of services in large urban centers.

Another example is the provision of a service channel in which public or private companies can publish remote services that eliminate the need for the customer to travel, such as scheduling consultations or surveying and checking documentation.

BUS's business model is based on providing relevant information to citizens about the cities in which they live, especially with regard to better use of public transport and its associated services.

In addition, the platform seeks to contribute to the sustainable development of cities, being a channel for sharing knowledge and provision of public utility services for citizens, private companies and the public sphere.

8.3.1 Barriers and Drivers for the Implementation of the Analyzed Business Models

The low integration between transport systems in cities emerges as a barrier for the implementation of the value proposition of the business models analyzed here as examples of new services for public transport, based on the fact that many companies face difficulties in designing a service more suited to the needs of the end user than they could offer in a scenario where this level of integration was higher.

This is configured as greater effort of both management and operational levels of the business models in order to allow managers to access information from different public transport systems in cities and, thus, to design a value proposal aligned with the main gaps in the configuration of these systems, adding greater value to the population and for the transportation system of the city as a whole.

If from the transportation planning stage the focus on integration was greater, it would be possible to propose more attractive services to users, in which they could identify the value more easily, since it would result in more effective solutions when the intention of the business model was to increase the level of integration between transport systems.

In addition, the barrier of difficulties in accessing information on users' travel patterns on public transport systems is also evident. In this sense, the challenge is to obtain reliable information that allows business models to adapt and develop products focused on the reality of users.

Often, new business models in this field depend on open data about public transport systems so that they may provide better solutions to users, which is often not possible due to the lack of structured data in many cities around the world.

Therefore, investments in technology that enable companies to build robust databases for a better understanding of users' travel behavior patterns by themselves have proven to be a relevant driver to deal with these barriers, including as an alternative to offer aggregated and complementary mobility services to users.

In addition, the possibility of integration with databases from other companies, including from other sectors, has also been shown to be an important driver for the implementation of these business models, requiring a scenario in which there is greater cooperation among stakeholders interested in providing new mobility services to make the solutions feasible.

8.4 Concluding Remarks

It is evident that emergent countries like Brazil, due to their public transport system gaps, as well as the historical context in which this system was developed, the country has first prioritized alternatives to solve the structural issues of public transport before thinking of implementing automated solutions.

Therefore, it seems that innovation projects based on sustainability in ubiquitous mobility are very welcome, but they do not replace the need for a conventional public transport solution, on which most residents of the peripheries of large cities depend, whose perspective of employment and income clashes with the interest of the private sector that operates most public transportation services in Brazil. The challenge that is presented is the contribution that innovations of sustainable urban mobility support to mitigate the great and old problems which public transport faces in the country.

In this context, automakers will not lead the most relevant transformations since most of the initiatives aimed at contributing to reduce the gaps from the public transport in Brazil – and from the sustainable mobility transition in a broader sense – come from new players interested in developing business models in this field, especially nascent companies focused on implementation of new technologies for the provision of mobility services.

However, initiatives that contribute to the improvement of public transport conditions show us that no new single player will be able to cause systemic changes alone, demanding a higher level of dialogue between stakeholders involved with the mobility ecosystem in cities in order to lead us to a transition to more sustainable mobility.

It is expected that part of the opportunities discussed in this chapter will also serve as a reference for other emerging countries that may face similar challenges for the development of a more sustainable public transport.

References

Associação Nacional das Empresas de Transportes Urbanos (2017). Anuário NTU: 2016–2017/ Associação Nacional das Empresas de Transportes Urbanos. – Brasília: NTU. Available at: https://www.ntu.org.br/novo/upload/Publicacao/Pub636391736883773822.pdf

Berggren, C., Magnusson, T., & Sushandoyo, D. (2015). Transition pathways revisited. Established firms as multi-level actors in the heavy vehicle industry. *Research Policy, 44*(5), 1017–1028. https://doi.org/10.1016/j.respol.2014.11.009

Dijk, M., Orsato, R. J., & Kemp, R. (2013). The emergence of an electric mobility trajectory. *Energy Policy, 52*, 135–145.

Freyssenet, M. (2009). *The second automobile revolution: Trajectories of the world carmakers in the 21st century*. London: Palgrave.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy, 36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

IDB. (2020). *Policy to Tackle Covid-19 Recommendations for Latin America and the Caribbean.*. https://publications.iadb.org/publications/english/document/Public-Policy-to-Tackle-Covid-19-Recommendations-for%2D%2DLatin-America-and-the-Caribbean.pdf. Accessed 24 Jan 2021.

Loorbach, D. (2010). Transition Management for Sustainable Development. A Prescriptive, Complexity-Based Governance Framework. In Governance *23*(1), 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Marx, R., Mello, A. M., Zilbovicius, M., & Lara, F. F. (2015). Spatial contexts and firm strategies: applying the multilevel perspective to sustainable urban mobility transitions in Brazil. *Journal of Cleaner Production, 108*(Part A), 1092–1104. https://doi.org/10.1016/j.jclepro.2015.09.001

Orsato, R. J., Dijk, M., Kemp, R., & Yarime, M. (2011). The electrification of automobility: The bumpy ride of electric vehicles toward regime transition. In F. W. Geels, R. Kemp, G. Dudley, & G. Lyons (Eds.), *Automobility in transition?* New York: A Socio-Technical Analysis of Sustainable Transport. Routledge.

Roberts, C., Geels, F. W., Lockwood, M., Newell, P., Schmitz, H., Turnheim, B., et al. (2018). The politics of accelerating low-carbon transitions: Towards a new research agenda. *Energy Research & Social Science, 44*, 304–311. https://doi.org/10.1016/j.erss.2018.06.001

Sarasini, S., & Jacob, M. (2014). Past, present, or future? managers' temporal orientations and corporate climate action in the Swedish electricity sector. *Organization & Environment, 27*(3), 242–262.

Valsecchi Ribeiro de Souza, J., Marotti de Mello, A., & Marx, R. (2019). *When is an innovative urban mobility business model sustainable? A Literature Review and Analysis Sustainability, 11*, 1761.

Wright, L. (2011). Bus rapid transit: A review of recent advances. In H. Dimitriou & R. Gakenheimer (Eds.), *Urban transport in the developing world: A handbook of policy and practice* (p. 421e455). Cheltenham, UK: Edward Edgar.

Chapter 9
MaaS as a Catalyst for the Public Transport Revolution in Developing Countries

Rodrigo Marçal Gandia

Abstract The Mobility-as-a-Service phenomenon entails the integration of different public and private transport, considering public transport as a backbone. The applicability of MaaS schemes is closely related to efficient public transport networks, which is not a reality in several developing countries. In this chapter, we present a new perspective on MaaS. Thus, we believe that for a revolution in public transport, MaaS can be a catalyst. We consider MaaS as a business model that can be modular and adaptable to any reality. By considering public transport as the backbone (whether it is efficient or not) its eventual inefficiency can be balanced with the integration of private actors, corroborating with the context of smart cities, and new alternatives for private transport means (e.g., autonomous vehicles and shuttles). To this end, we consider precepts from business ecosystem, PSS, eco-innovation, consumer behavior – and the act of sharing. Approaches like these can guide the applicability of MaaS in the context of Smart Cities and new perspectives, such as Corporate MaaS and Rural MaaS.

Keywords MaaS · Public transport · Ecosystem

9.1 Introduction

Since the beginning of humanity, mobility has been a concern for human beings. Currently, we have Autonomous Vehicles (AVs), but the search for better forms of mobility started as soon as the first man was as far as his legs could reach.

We certainly do not want to compare the current urban complexity of a megalopolis like São Paulo, Paris, or New York to the simplicity of getting around on foot

R. M. Gandia (✉)
Universidade Federal de Lavras, Lavras, Brazil
e-mail: romgandia@gmail.com

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_9

in primate times but rather to illustrate how the essence of mobility can be applied to these two examples similarly.

When a Parisian wakes up in the morning and walks to a subway station to catch the RER[1] and get to his job, the goals in terms of mobility are similar to that of Homo Erectus who moved in search of food more than 500,000 years ago; leave point A to reach point B. Although much has evolved since then, the essence of mobility remains, and all the other consequences of this are ways to achieve this goal in a more efficient, systemic, sustainable, and/or comfortable way. With the evolution of private automobiles, for example, we stopped using the horse as the primary form of transport and started to rely on internal combustion engine machines[2] that could help us in our mobility in a much more comfortable, efficient way, and, as everything indicated at the time, more sustainable.[3] In July 2019, a conference on urban mobility was held in Helsinki with the aim of discussing different perspectives on public transport and our cities. At that time, the urban designer Mikael Colville-Andersen commented that, in the early 1920s, the streets used to be an extension of our homes' backyards. Before the widespread adoption of private cars, we had space to walk, talk, and spend time with friends on the streets with greater freedom and security. Facts that are no longer a reality.

Nevertheless, then, what has changed? The answer: we lost the fight against cars.

Of course, this is an extremist answer ... In general, the fact is that this happens because the design of our cities brings a favorable perspective in all aspects to automobiles, and makes it difficult for the circulation of pedestrians or other modes of transport.

Have you stopped for a moment to think that approximately 2/3 of the urban space, considering sidewalks and streets, are destined for cars? – In many cases, this ration can be even greater.

However, in the Finnish capital, this is not a reality. Over there, what happens is just the opposite. The streets were narrow, and the sidewalks were wide. Cars share their space with trams. Public transport operates at an impressive pace with very reasonable waiting times, and in excellent conditions. Bike paths and shared bicycle stations are scattered throughout the city, offering access to a significant portion of the population. The result of that? Life without a car there is a feasible possibility.

With all this effort for more fluid urban mobility, it is no coincidence that the concept of Mobility as a Service (MaaS) was born in Finland in 2014. MaaS is a distribution model of mobility that delivers users' transport needs via a single service provider's interface by combining different transport modes to offer a tailored mobility package – just as a monthly mobile phone contract (Hietanen, 2014).

[1] For those who have never had the privilege of living or going to Paris, RER is one of the main train lines that run through the French capital.

[2] Some people say that humanity will never trust autonomous vehicles (...) discussions for other times.

[3] One of the great promises of automobiles shortly before its vertiginous rise in 1910 was the ideal replacement of waste left by horses (shit). The fact is cars would then no longer "pollute" cities—one of the great mistakes of our modern civilization.

From its early days in 2014, MaaS has acted as a disruptive catalyst against the "obligation" of owning a car (e.g., Whim app[4]). Most literature discussions relate to the balance between public and private transport, offering commute alternatives that are most convenient at the moment (Jittrapirom et al., 2017; Kamargianni, Li, Matyas, & Schäfer, 2016).

Several authors state that public transport entails the backbone of MaaS systems (Karlsson, Sochor, & Strömberg, 2016; Pangbourne, Stead, Mladenović, & Milakis, 2018; Sochor, Arby, Karlsson, & Sarasini, 2017), which undoubtedly contribute to the spread of MaaS schemes.

How Will MaaS perform in places where public transport is not efficient? That was the first question we asked ourselves when using Whim in Helsinki.

Nevertheless, before trying to answer this question, it is essential to highlight the correlation between the need for car ownership vs. the inefficiency of public transport in some underdeveloped countries, such as Brazil.

In Brazil, the "success" of a car is correlated to public transports' inefficiency. Delays, unavailability, little coverage, poor infrastructure, among other aspects, can be mentioned here (see more in Chap. 8). Also, safety is another factor that must be taken into account. Unlike other countries on the north axis, in Brazil, it is not very safe to use public transport late at night, for example. In addition, for many Brazilians, the car is much more than an instrument of mobility and assumes a symbolic role of desire and status. The compilation of instrumental, symbolic, and affective factors (Steg, 2005) and the theory of practice approach (Reckwitz, 2002; Warde, 2005) contributes to this. However, we argue that that the car acts mainly as "mobility insurance" (Flügge, 2017). He's there, as an "ambassador" for individual freedom, available in your garage to take you anywhere, anytime.

Thus, owning a car means that the value proposal delivered by any other means of public transport, in many cases, is not sufficiently superior to leaving a private vehicle in the garage. According to Sprei (2018), the private-owned vehicle is still holding its dominant position, and shared mobility *per se* might not be attractive enough to disrupt the transportation system.

Although well studied, like any other new approach, MaaS concepts are still incipient in the literature (Ambrosino, Nelson, Boero, & Pettinelli, 2016; Matyas & Kamargianni, 2018; Strömberg, Rexfelt, Karlsson, & Sochor, 2016). Thereby, it is worth highlighting that all current studied MaaS systems take place in developed countries (Jittrapirom et al., 2017; Kamargianni et al., 2016), and the advances in MaaS are being constructed especially in Europe (Hensher, 2017).

In this way, bringing studies about its evolution from places where public transport is mostly efficient can come loaded with biases when incorporated without filters to other realities, as is Brazil's case. Back to our concern made in Helsinki; "Would it be possible to implement MaaS models in places where public transport is inefficient and add value to the user?"

[4] Whim is the MaaS operator available in Helsinki. It works as an app on the smartphone, in which it is possible to choose the transport modes better fit it to the use.

To try to answer this question, we bring an analysis under a new conceptual MaaS perspective proposed by Gandia, Antonialli, Sugano, and Nicolaï (2019), built from the precepts from business ecosystem (Moore, 1993), Product-Service System (Tukker, 2004), eco-innovation (Rennings, 2000), and consumer behavior (Belk, 2010).

Based on this approach, it is possible to build value for MaaS, sufficiently superior to private vehicles' exclusive use. Thus, MaaS initiatives, implemented in an orchestrated way in specific locations, can act as catalysts for public transport use.

9.2 MaaS as a Disruptive Innovation and AVs as a Disruptive Technology

We understand that MaaS and AVs present distinctions in terms of disruption. The former can be considered a disruptive innovation by creating new markets without the need to deliver a breakthrough technology. According to Flügge (2017), all the solutions for MaaS are here, and we need to orchestrate them. For the latter, we understand it as a disruptive technology for the utterly advanced technology of AVs regarding the traditional automotive industry.

The MaaS 'potential to create new markets (Mulley, 2017) is closer to the new market disruption concepts proposed by Christensen and Raynor (2003). Corroborating with this, Sprei (2018) states that to be genuinely disruptive shared mobility has to have the potential to grow beyond niches, and one way to improve this attractiveness is combining different services, such as MaaS. However, the technological disruption of AVs does not necessarily deliver the creation of new markets. For instance, if autonomous taxis replace the driver, they will be like other taxis. Complementary, we cannot rely on those technological innovations alone, leading to a desirable disruption from society's point of view (Sprei, 2018).

In this sense, MaaS and AVs will not be, *per se*, the disruptive solution for urban mobility. We believe that they should be analyzed in a complementary way to achieve a disruption in mobility.

9.3 Smart Cities and the Ecosystem of Mobility

With rapid global advances and organizational complexity, significant changes occur in the business environment, especially concerning technology, physical environment, market forces, consumer behavior, and finance (Chesbrough, 2011).

The concept of smart cities proposes that the evolution of digital technologies increasingly connects with traditional structures combined with ICTs (Batty et al., 2012). The interconnected complexity of smart cities is increasingly part of the ecosystems of our urban centers. In this sense, the notion of ecosystems has gained attention in academic literature as a concept to understand and explain the complexity of the interconnected nature of the modern business environment (Durst & Poutanen, 2013; Lehto, Hermes, Ahokangas, & Myllykoski, 2013).

Since the seminal work of business ecosystem (Moore, 1993), several authors agree that the definition and concept of an ecosystem are unclear, and there is still much work to be done to establish it (Daidj, 2011; Iivari, Ahokangas, Komi, Tihinen, & Valtanen, 2016; Koenig, 2012; Peltoniemi & Vuori, 2004; Tsujimoto, Kajikawa, Tomita, & Matsumoto, 2017).

In this way, many different definitions of the business ecosystem emerge. Iivari et al. (2016) affirm that a business ecosystem refers to a network of organizations involved in developing and delivering a specific product/service through competition and cooperation. However, for Peltoniemi and Vuori (2004), there is no need for government interventions to a business ecosystem survivor because they are self-sustaining.

In a MaaS context, many authors contributed to the Business Ecosystem enforcement (Gandia, Antonialli, et al., 2019;Jittrapirom et al., 2017 ; Kamargianni & Matyas, 2017). MaaS ecosystem is built on interactions between different groups of actors through a digital platform, under different layers: demanders of mobility (i.e., private customer or business customer), a supplier of transport services (i.e., public or private), and platform owners (i.e., third party, public transport provider, public authorities).

Other actors can also cooperate to enable the service's functioning and improve its efficiency: local authorities, payment clearing, telecommunication, and data management companies (Jittrapirom et al., 2017; Kamargianni & Matyas, 2017).

From a new perspective, in an initial effort, Gandia, Antonialli, et al. (2019) analyzed MaaS under the ecosystem approach, based on the precepts of eco-innovation and the Product-Service System (PSS).

A PSS concept can be defined as an integrated bundle of products and services that aims to create customer utility and generate value (Boehm & Thomas, 2013). Similarly, Annarelli, Battistella, and Nonino (2016) state that a PSS is a business model focused on providing a marketable set of products and services designed to be economically, socially, and environmentally sustainable, with the final aim of fulfilling customer's needs. According to Centenera and Hasan (2014), a PSS is an integrated combination of products and services for optimal consumption. Besides the multiple definitions, we observed that a PSS aims to create value for users by setting in joint offer products and services.

This approach proposes that, far beyond delivering value when it comes to mobility, MaaS models are part of an ecosystem that must be understood, from the value delivered to the user to the sustainability of the proposed mobility models. This model is present in the next section.

9.4 Unveiling MaaS: The Theoretical Tripod of Business Ecosystem, PSS and Eco-innovation

One of the significant criticisms about MaaS is the lack of theoretical support. In this sense, Gandia, Antonialli, et al. (2019) tried to bridge this and support MaaS from the perspective of three main concepts: Business Ecosystem, Product-Service System, and Eco-Innovation.

In general, the Business Ecosystem theory's assumption states that MaaS has several agents (competitors or not) that must be combined and act collaboratively. For this, assigning MaaS as a result-oriented PSS is essential, because only then can multiple solutions be combined to offer the best-expected result. From a customer perspective, an integrated solution allows for 'one-stop-shopping' and enhanced efficiency and effectiveness (Kuijken, Gemser, & Wijnberg, 2017).

However, if all this effort is not enough to contribute to a favorable sustainability scenario, the model should not be applied. Gandia, Antonialli, et al. (2019) argue that a successful MaaS system is one that not only integrates transport modals but one that considers the eco-innovation concept by attracting to its platform both public transport users and car owners.

Eco-innovation can be conceived as a conventional innovation when they are concerned with the environment and sustainability (Aloise & Macke, 2017; Rennings, 2000). Mainly for MaaS we consider eco-innovation to reduce car ownership or more efficiently use it by user and "not-sharing" peer-to-peer commuters.

When analyzing MaaS in developing countries (with their public transport inefficiencies), it is unlikely that the platform would attract most private vehicle users (as in scenarios, such as Helsinki or Stockholm). On its current configuration, with no adaptations to the local reality (such as the Brazilian context), MaaS is doomed to failure. Thus, to minimize any rebound effects (Manzini & Vezzoli, 2003), a new MaaS perspective was proposed, MaaS 2.0 (Gandia, Antonialli, et al., 2019).

9.5 A New Perspective: MaaS 2.0

What reason would you have to set aside the car, the "ambassador of freedom", to use any other transport model? That question supports the discussions towards proposing this new perspective of MaaS, in version 2.0 (Gandia, Antonialli, et al., 2019). Such a proposal does not aim at eliminating private vehicles. Its forerunner, Sampo Hietanen, makes it quite clear that MaaS model is not for everyone and is not its intention to replace vehicle ownership (Hietanen, 2019).

However, according to Gandia, Antonialli, et al. (2019), MaaS 2.0 proposes that, for the model to be well applied, it is necessary that a substantial number of private vehicle owners shift to the MaaS model, even in places where public transport is not as efficient.

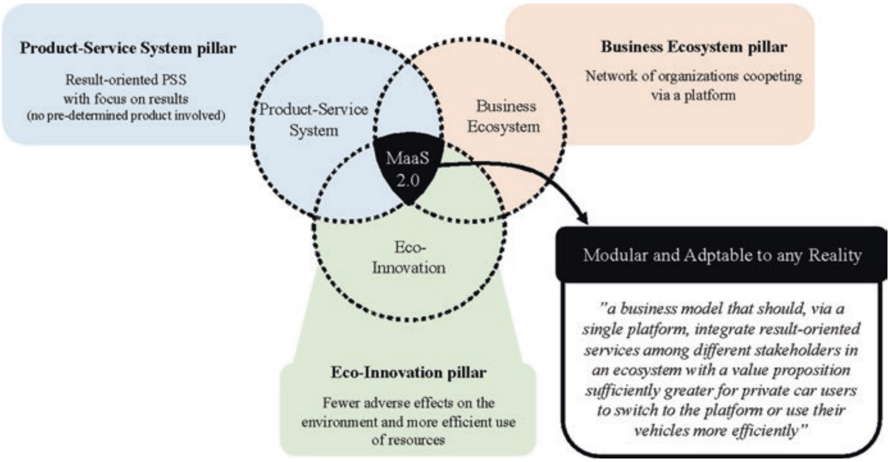


Fig. 9.1 MaaS 2.0 under the theoretical tripod of PSS, Business Ecosystem, and Eco-Innovation. (Source: Adapted from Gandia, Antonialli, et al., 2019).

Furthermore, we believe that to "win the fight" against "car need seekers",[5] more than integrating public and private transport is necessary. To enable this shift, MaaS must first be treated as a business model, where contextual factors must be analyzed, and the value generation for each user segment becomes a premise. Thus, Gandia, Antonialli, et al. (2019) propose that MaaS 2.0 should integrate not only transport modes but also several actors of an ecosystem to deliver value to the user. In this way, the theoretical tripod of PSS, Ecosystem, and Eco-innovation can be met (Fig. 9.1).

Thus, the main difference between the current MaaS and MaaS 2.0 is that the MaaS evolution seeks to share and integrate transport modes and other stakeholders (not directly related to mobility). By this, other industries, such as entertainment, retailers, food service, and even housing, can be a part of MaaS 2.0. At this level, the need to own a car could be drastically reduced, while the ecosystem complexity would increase (Gandia, Antonialli, et al., 2019).

This model's premise is that the greater the user's value, the greater the chance that he will not use a private vehicle. However, to deliver more value, a more significant number of stakeholders in this ecosystem is needed to generate network effects (Gandia, Antonialli, et al., 2019), which makes it more complex, following the precepts of Tukker (2004) and result-oriented PSS.

As shown in Fig. 9.1, MaaS 2.0 is considered "a business model that should, via a single platform, integrate result-oriented services among different stakeholders in an ecosystem with a value proposition sufficiently greater for private car users to switch to the platform or use their vehicles more efficiently" (Gandia, Antonialli, et al., 2019, p13.).

[5] We tried here to bring a term to the "excessive desire to use vehicles", I do not know if I was successful, but that was the idea of this word.

With that, MaaS can be considered as a modular business model that can be adaptable to several realities. Under this view, the dynamics that permeate MaaS 2.0 are correlated with Smart Cities functionalities' precepts when related to smart mobility typology, which must meet the sustainable, innovative, and safe transport system (Batty et al., 2012).

9.6 Low- or High-Tech Transport Modals Which Would Better Fit MaaS?

When dealing with MaaS, especially from a smart cities' perspective, the need to bring precepts in which cutting-edge technology is needed comes to the forefront. The fact is the ICTs and the two-sided market platform technologies required for the MaaS to function (Giesecke, Surakka, & Hakonen, 2016; Ho, Hensher, Mulley, & Wong, 2018; Jittrapirom et al., 2017; Kamargianni et al., 2016; Matyas & Kamargianni, 2018; Utriainen & Pöllänen, 2018) the technological capacity of the transport modes that are part of their ecosystem must be treated differently.

This means that there are low-tech alternatives within the modal-split to implement a MaaS business model. For instance, sharing a car may be used as a transport modal in a MaaS system, and casual carpooling may be an alternative to implement MaaS in the context where this transport mode is accepted (Gandia et al., 2019). Therefore, the choice of transport modes must be oriented by the MaaS ecosystemic business model based on these users' result-oriented value proposition.

Regarding Autonomous Vehicles, it is undeniable that this technology will affect the future modal-split of urban mobility. To achieve AVs' dissemination, technical aspects are already waiting for the evolution of non-technical knowledge fields, such as ethics, laws, public policies, and deep studies on consumer behavior (Gandia et al., 2018).

However, although AVs' technological development can be considered globally, local specificities should be taken into account, considering social, economic, legal, and governmental particularities as determinant factors (Gandia et al., 2020). More details on AVs are found in chapters; 3 – legislation aspects of AVs, 4 – public policies for AVs, and 10 – governance models for urban mobility innovations).

Thus, the answer to the question "low- or high-tech transport modals, which would better fit MaaS?" is dependent on the context in which the MaaS business model will be employed. Furthermore, for MaaS, the value proposal must be aligned with proposition variables to obtain the best response to local users' pains and needs.

9.7 Conclusion

The discussions in this chapter suggest several propositions that sustain MaaS to act as a catalyst for the public transport revolution in developing countries.

First, it is worth highlighting that mobility solutions' technical development is not the solution for urban mobility. Similarly, the phenomenon of Mobility as a Service should be better analyzed by other perspectives. In order to take place in the future of urban mobility, MaaS must be considered as a modular and adaptable business model, applicable to several contexts (the efficiency – or inefficiency – of public transportation should not be a limiting factor). For this, the business model of MaaS should be established under the ecosystemic approach – and sustainability should not be considered as an intrinsic feature in a MaaS business model.

As a business model, MaaS can be modular and adaptable. As previously seen, its applicability can be derived from the incorporation of low-tech practices (such as casual carpooling in small towns) to the technological disruption presented by autonomous vehicles and shuttles. The fact is that it is precisely this modularity of MaaS that makes it independent from high-tech transport modes, allowing us to consider it as a disruptive innovation.

This innovative ecosystem business model must take into account consumer acceptance and the transport modes that fit the specific context established (either for developed or developing economies). In other words, a successfully implemented MaaS system in Sweden will likely not have the same success rates in Brazil, whether or not "tropicalized".[6]

We are certainly not saying that disruptive technologies such as autonomous vehicles are irrelevant or obsolete for the Brazilian context (see more in Chap. 8). However, we consider that AVs' implementation will complement, in specific contexts, the demands of users in a MaaS' ecosystem. The deployment of AVs can also occur outside a MaaS business model ecosystem, in specific places and contexts.

In this sense, AVs should be considered one among several elements in the future urban mobility ecosystem. One example to be considered is the optimization of routes based on AVs' use and sharing (Mourad, Puchinger, & Chu, 2019), which may or may not be present in a MaaS model. However, we believe that this is a reality in the medium and long term, in more developed countries, without many perspectives in underdeveloped countries, precisely in which public transport is most needy and inefficient (see more in Chap. 8).

Second, another essential point to be reinforced is related to the balance between public and private transport coming from the practices of MaaS. Whether in countries where public transport is efficient or not, the fact is that Brazilian urban mobility is strangled by private vehicles, and the integration solution is the one that promotes better prospects to relieve this channel.

Thus, MaaS, as a business model, can offer solutions that deliver value to the user in a creative, low-cost manner, not necessarily relying on cutting-edge technologies. As examples, it is possible to mention, free rides as a strategy to implement MaaS in small towns (Gandia, Oliveira, et al., 2019), the MaaS used by companies, CMaaS (Hesselgren, Sjöman, & Pernestål, 2020), and the use of MaaS

[6]Tropicalization means adapting the characteristics of a product or service to the realities of the local context. The term tropicalize serves mainly tropical countries, such as Brazil.

in rural regions (Barreto, Amaral, & Baltazar, 2018; Eckhardt, Nykänen, Aapaoja, & Niemi, 2018).

Indications like these bring MaaS adaptability and modularity perspectives to be applied in a context where AVs are a reality, even regions where casual carpooling is a possibility.

Aspects like these make MaaS, employed as a business model, in its 2.0 vision, to act as a catalyst for the public transport revolution, regardless of the composition of the ecosystem's transport modes (low- or high-tech), it is possible to deliver value to users and contribute to the balance between the use of public and private transport.

References

Aloise, P. G., & Macke, J. (2017). Eco-innovations in developing countries: the case of Manaus Free Trade Zone (Brazil). *Journal of cleaner production, 168*, 30–38.

Ambrosino, G., Nelson, J. D., Boero, M., & Pettinelli, I. (2016). Enabling intermodal urban transport through complementary services: From flexible mobility services to the shared use mobility agency: Workshop 4. Developing inter-modal transport systems. *Research in Transportation Economics, 59*, 179–184.

Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. *Journal of Cleaner Production, 139*, 1011–1032.

Barreto, L., Amaral, A., & Baltazar, S. (2018). Mobility as a Service (MaaS) in rural regions: An overview. In *2018 International Conference on Intelligent Systems (IS)* (pp. 856–860). IEEE.

Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., et al. (2012). Smart cities of the future. *The European Physical Journal Special Topics, 214*(1), 481–518.

Belk, R. (2010). Sharing, the journal of consumer research inc. *Journal of Consumer Research, 36*(5), 715–734.

Boehm, M., & Thomas, O. (2013). Looking beyond the rim of one's teacup: A multidisciplinary literature review of product-service systems in information systems, business management, and engineering & design. *Journal of Cleaner Production, 51*, 245–260.

Centenera, J., & Hasan, M. (2014). Sustainable product-service system. *International Business Research, 7*(7), 62.

Chesbrough, H. (2011). Bringing open innovation to services. *MIT Sloan Management Review, 52*(2), 84–90.

Christensen, C. M., & Raynor, M. E. (2003). *The innovator's solution: Creating and sustaining successful growth*. Boston: Harvard Busniess School Press.

Daidj, N. (2011). Les écosystèmes d'affaires: une nouvelle forme d'organisation en réseau? *Management & Avenir, 6*, 105–130.

Durst, S., & Poutanen, P. (2013). Success factors of innovation ecosystems – Initial Insights from a literature review. In: Smeds R and Irrmann O (Eds) co-create 2013: The Boundary Crossing Conference on Co-Design in Innovation: 27–38. Aalto University Publication series science + Technology 15/2013.

Eckhardt, J., Nykänen, L., Aapaoja, A., & Niemi, P. (2018). MaaS in rural areas-case Finland. *Research in Transportation Business & Management, 27*, 75–83.

Flügge, B. (2017). *Smart mobility–connecting everyone: Trends, concepts and best practices*. Springer.

Gandia, R. M., Antonialli, F., Cavazza, B. H., Neto, A. M., Lima, D. A. D., Sugano, J. Y., et al. (2018). Autonomous vehicles: Scientometric and bibliometric review. *Transport Reviews, 39*(1), 9–28.

Gandia, R. M., Antonialli, F., Sugano, J., & Nicolaï, I. (2019). The business eco-system of mobility as a service (MaaS) as a product-service system (PSS): An eco-innovation. In SemeAd, 2019, São Paulo. XXII.

Gandia, R. M., Oliveira, J., Antonialli, F., Patrício, L., Sugano, J. Y., Nicolaï, I., & Oliveira, I. (2019). Casual carpooling as a strategy to implement mobility-as-a-service (MaaS) in a developing country. In 27th International Colloquium of Gerpisa., 2019, Paris. Paradigm shift? The Automotive Industry in Transition.

Gandia, R. M., Veroneze, R. B., Antonialli, F., Cavaza, B. H., Sugano, J. Y., & Nicolai, I. (2020). The quintuple helix model and the future of mobility: The role of autonomous vehicles in a developing country. *Revista de Administração, Sociedade e Inovação, 6*, 52–70.

Giesecke, R., Surakka, T., & Hakonen, M. (2016, April). Conceptualising mobility as a service. In *2016 eleventh international conference on Ecological Vehicles and Renewable Energies (EVER)* (pp. 1–11). IEEE.

Hensher, D. A. (2017). Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change? *Transportation Research Part A, 98*, 86–96.

Hesselgren, M., Sjöman, M., & Pernestål, A. (2020). Understanding user practices in mobility service systems: Results from studying large scale corporate MaaS in practice. *Travel Behaviour and Society, 21*, 318–327.

Hietanen, S. (2014). "Mobility as a Service"—The new transport model? *Eurotransport, 12*(2), 2–4.

Hietanen. S. (2019). Sampo's blog: Attacks and answers about MaaS. Whim. Retrieved on December 26, 2020, from http://twixar.me/wq31

Ho, C. Q., Hensher, D. A., Mulley, C., & Wong, Y. Z. (2018). Potential uptake and willingness-to-pay for mobility as a service (MaaS): A stated choice study. *Transportation Research Part A: Policy and Practice, 117*, 302–318.

Iivari, M. M., Ahokangas, P., Komi, M., Tihinen, M., & Valtanen, K. (2016). Toward ecosystemic business models in the context of industrial internet. *Journal of Business Models, 4*(2), 42–59.

Jittrapirom, P., Caiati, V., Feneri, A. M., Ebrahimigharehbaghi, S., Alonso González, M. J., & Narayan, J. (2017). Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges.

Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A critical review of new mobility services for urban transport. *Transportation Research Procedia, 14*, 3294–3303.

Kamargianni, M., and M. Matyas (2017). The business ecosystem of mobility as a service. In *96th Transportation Research Board (TRB) annual meeting*, Washington DC, 8-12 January 2017. Retrieved on July 7, 2019, from: http://twixar.me/bq31

Karlsson, I. M., Sochor, J., & Strömberg, H. (2016). Developing the 'Service' in mobility as a service: experiences from a field trial of an innovative travel brokerage. *Transportation Research Procedia, 14*, 3265–3273.

Koenig, G. (2012). Le concept d'écosystème d'affaires revisité. *M@n@gement, 15*(2), 209–224.

Kuijken, B., Gemser, G., & Wijnberg, N. M. (2017). Effective product-service systems: A value-based framework. *Industrial Marketing Management, 60*, 33–41.

Lehto, I., Hermes, J., Ahokangas, P., & Myllykoski, J. (2013). Collaboration in cloud businesses – Value networks and ecosystems. Communications of the Cloud Software (ISSN 22425403). Discussion paper.

Manzini, E., & Vezzoli, C. (2003). A strategic design approach to develop sustainable product service systems: Examples taken from the 'environmentally friendly innovation'Italian prize. *Journal of cleaner production, 11*(8), 851–857.

Matyas, M., & Kamargianni, M. (2018). The potential of mobility as a service bundles as a mobility management tool. *Transportation, 46*(5), 1951–1968.

Moore, J. F. (1993). Predators and prey: A new ecology of competition. *Harvard Business Review, 71*(3), 75–86.

Mourad, A., Puchinger, J., & Chu, C. (2019). A survey of models and algorithms for optimizing shared mobility. *Transportation Research Part B: Methodological, 123*, 323–346.

Mulley, C. (2017). *Mobility as a Services (MaaS) – does it have critical mass ? 1647(March)*. https://doi.org/10.1080/01441647.2017.1280932

Pangbourne, K., Stead, D., Mladenović, M., & Milakis, D. (2018). The case of mobility as a service: A critical reflection on challenges for urban transport and mobility governance. *Governance of the Smart Mobility Transition*, 33–48.

Peltoniemi, M., & Vuori, E. (2004, September). Business ecosystem as the new approach to complex adaptive business environments. *Proceedings of eBusiness Research Forum, 2*(22), 267–281.

Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European Journal of Social Theory, 5*(2), 243–263.

Rennings, K. (2000). Redefining innovation e eco-innovation research and the contribution from ecological economics. *Ecological Economics, 32*(2), 319e332. https://doi.org/10.1016/S0921-8009(99)00112-3

Sochor, J., Arby, H., Karlsson, M., & Sarasini, S. (2017). A topological approach to Mobility- as-a-Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals. In *1st International Conference on Mobility as a Service (ICOMaaS),* Tampere, Finland.

Sprei, F. (2018). Disrupting mobility. *Energy Research & Social Science, 37*, 238–242.

Steg, L. (2005). Car use: lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A: Policy and Practice, 39*(2-3), 147–162.

Strömberg, H., Rexfelt, O., Karlsson, I. M., & Sochor, J. (2016). Trying on change–Trialability as a change moderator for sustainable travel behaviour. *Travel Behaviour and Society, 4*, 60–68.

Tsujimoto, M., Kajikawa, Y., Tomita, J., & Matsumoto, Y. (2017). A review of the ecosystem concept—Towards coherent ecosystem design. *Technological Forecasting and Social Change*.

Tukker, A. (2004). Eight types of product-service system: Eight ways to sustainability? Experiences from suspronet. *Business Strategy and the Environment, 13*(4), 246–260. https://doi.org/10.1002/bse.414

Utriainen, R., & Pöllänen, M. (2018). Review on mobility as a service in scientific publications. *Research in Transportation Business & Management*.

Warde, A. (2005). Consumption and theories of practice. *Journal of Consumer Culture, 5*(2), 131–153.

Chapter 10
Reflexions on Urban Mobility Governance: Moving Towards Tomorrow's Robomobility

Danielle Attias

Abstract The question of urban mobility governance is a challenge for all cities worldwide. Economic, financial, social, and environmental issues are at the heart of ecological transition programs in many major cities globally. This new governance model concerns public transport and the management of innovative mobility, including mobility on-demand. However, the modes of management of public transport are contrasted, varying according to the geographical location of cities, citizens' way of life, and the history of each metropolis. What remains common to all cities is an ambition and a desire to implement in their mobility systems radical innovations such as autonomous shuttles and digitalization tools such as MaaS (Mobility-as-a-Service). The future of mobility is part of a robomobility approach, including autonomous vehicles. This forward-looking vision will radically challenge the relationships between users, citizens, and city governance.

Keywords Transport Organization Authorities · Innovative solutions for new public transport mobility · Shared public transport on demand

10.1 Introduction

The governance of public transport is radically changing, resulting in major impacts on the development model of the world's big cities. These impacts are economic, financial, social, and environmental. Governance is a crucial issue in today's

D. Attias (✉)
Industrial Engineering Laboratory, École CentraleSupélec, Université Paris-Saclay, Gif-sur-Yvette, France
e-mail: danielle.attias@centralesupelec.fr

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9_10

megacities, with the standard model being judged as inefficient, over-segmented, and lacking global vision in terms of public transport and land planning (Meijer & Bolívar, 2016; Pinson, 2009). Cities need to respond to a range of mobility demands from citizens, build new infrastructures, and ensure sustainable economic development (Auvinen & Tuominen, 2014). As a result, supra-territorial decision-making bodies are emerging in big cities around the world (for instance, in Montreal, Tokyo, Luxembourg, Singapore, Lyon, and Geneva).

To gain greater insight into this new governance of public transport, we review the current situation in different cities in the world that symbolize this new approach (Sect. 10.2). A study of economic and environmental issues is needed to understand the radical shift in this model (Sect. 10.3). However, this new type of governance highlights another phenomenon, which is the establishment of disruptive innovation in public transport. While over the last 150 years innovation was restricted to the private domain (mainly led by the automotive industry), today it is largely financed and implemented in the public transport sector. Lastly, building on these radical innovations, on-demand transport is set to be a major feature of tomorrow's public transport (Sect. 10.4).

10.2 Current Global Situation of New Means of Governance

Public transport governance has changed radically since 2015. This phenomenon is visible in most of the world's megacities in Asia, Europe, and North America. Clearly, this change in governance models is a key factor in the public transport revolution. An overview of the current situation in major cities makes it easier to understand the causes of this shift.

10.2.1 Common Causes of the Model Change

When studying the world's megacities, what is striking is the shared diagnosis made at the same moment. In point of fact, the major causes of a change in governance are rising urbanization: two-thirds of the world's population will live in urban areas by 2050 (Van Audenhove, Dauby, Korniichuck, & Pouraix, 2014), meaning cities will need to better deal with congestion, pollution, negative health impacts, and deteriorating quality of life.

- The emergence of new mobility uses and users that support sustainable, efficient urban mobility systems (Jakson, 2019).
- The urgent need for an urban energy transition strategy to promote decarbonized public transport and encourage new, active mobility options, e.g., cycling, carsharing, and carpooling, (ADEME, 2019).

- The dispersion and compartmentalization of "traditional" public transport, which can no longer be envisaged without fully networking these types of transport, including bus, metro, and tram lines. Public transport will need to tackle major challenges to manage transport costs and anticipate investments (Litman, 2020). The current aging set-up is inefficient, it does not aim on optimizing journeys, and in particular it does not satisfy customers due to insufficient quality and unclear information on available journeys and frequency.
- Demand from passengers for faster information and for a multi-modal system throughout the territory, allowing users to choose at any moment the type of transport that suits them best.
- The need to standardize transport systems for greater fluidity and to group together a large number of mobility actors to optimize and efficiently manage transportation (Courmont & Le Galès, 2019).
- The unprecedented development of "smart" mobilities, like digital transport systems in which vehicles are increasingly connected to their environment (Geoffron, 2017).

These different points clearly show that governance is a crucial issue for cities, which in turn urgently need to tackle these challenges by implementing new transport policies.

10.2.2 Notion of a Transport Organization Authority

Transport Organization Authorities (TOAs) are a new governance model for transportation in the world's megacities. The principle behind TOAs was set out by Denis Coderre, Mayor of Montreal and President of the Montreal Metropolitan Area (Marchal, 2013), "*The proposed governance model is based on the principle that local politicians, who are familiar with their citizens' needs, should have the necessary powers to serve them better in terms of public transport*". The key idea behind a TOA is to bring citizens and politicians closer together.

For the first time in the history of transport, assemblies of local politicians are directing, steering, and operating major investment decisions on public transport. In its annual report (2019–2020), the association *Trajectoire Québec*, which is involved in the promotion of citizens' rights in public transport, pointed out regarding this new means of governance of the AQTR (*Association Québécoise des Transports*) in these terms: "*metropolitan issues require a collaboration process between politicians, mobility partners and civil society*".

Another efficient, innovative factor is its simplified governance structure. In Lyon, Sytral (a public entity for the Rhône administrative area and metropolitan Lyon) became the Rhône AOT (*Autorité Organisatrice des Transports en commun du Rhône*), the only structure in France to organize all urban and interurban services and networks on this scale.

This specific institutional character makes it a forerunner on both local and national levels. Sytral was in fact one of the first innovative governance models in public transport, serving 290 municipalities representing 1.7 million inhabitants. Mrs. Bouzerda, President of Sytral from 2017 to 2020, sees the entity as the fruit of a "*political ambition… and a will to win over localities that were hostile to Sytral but that needed to be reached by public transport in the interest of their inhabitants*" (In-person interview 19/11/2020).

Sytral is managed by a committee, a decision-making body that operates like a board of directors and comprises 31 elected representatives. These members are appointed for the duration of their mandate and renewed (or not), following local council and city elections.

This question of changing elected representatives in fact raises political questions of whether or not continuity is important in urban transport planning, because, depending on the political leanings of these elected representatives, strategic choices are either pursued or undone.

In September 2020, the new president of Sytral, Bruno Bernard, who is also president of the Metropolis of Lyon, announced his targets (Lyan, 2020): "*to strengthen coordination and dialogue between mobility actors and better understand the challenges of setting up mobility services*". This new objective, which is written into the French Law on Mobility Orientation (LOM, 2019), has resulted in a committee of representatives from the economics field, associations and universities, along with users and consumers. The committee will need to be consulted before any substantial changes can be made to mobility options, pricing, the quality of services, and information. This once again illustrates a clear ambition to move the decision-making process closer to citizens.

For federal states like Switzerland, the legitimate scale for a TOA is the state or the city. The State of Geneva is therefore the competent authority to manage and organize all types of mobility, with a large network of buses, trams, trains, and boats that allows users to travel throughout the locality. The network is managed by the Geneva Public Transport (TPG). This means of governance is not really new in Geneva, but what is interesting is that it has to consider the views expressed by Genevans, including the price of transport tickets. Following referendums in 2014 and 2017, for example, Genevan citizens rejected an increase in transport prices. On September 21, 2017, the Grand Council of Geneva voted a law preventing the canton from modifying the tariffs, and compensating TPG's losses with an annual payment of ten million Franc Suisse or Franc Confédération Helvétique (CHF)[1] in order to respect the will of the Genevan population.

In Geneva, the impact of motorized traffic on the environment is high and the city's elected officials are keen to promote a sustainable urban model. Public transportation is promoted because it is less polluting and more economical: the cost per

[1] 1 CHF= 0,93 €

km is 44 CHF cents for a private car and 22 CHF cents for public transport[2] (Ravalet, De Lapparent, Kaufmann, & Klein, 2019). Numerous alternatives to private cars exist: bicycles, walking, rollerblades, scooters, skateboards, car pools, and carsharing. To encourage citizens to adopt more sustainable modes of transport, the city subsidizes associations that provide this type of direct service to the public.

In the city state of Singapore, mobility and transportation are totally controlled by the state (Laurent, Prédali, Cariou, & Wolf, 2019). The government of Singapore, led by a single party, obliges the TOA to set up a contract-based system with network managers, in particular bus operators. This centralized governance makes it easier to monitor service quality, and to target optimum user satisfaction (Razemon, 2014). Since 2016, a new incentive system has been in place to improve the assignment of bus line operations. This new transport organization can be summed up as, "one head, two arms" (Kemmeter, 2020).

Two public transport companies cover the whole island of Singapore: MRT (Mass Rapid Transit) for the heavy rail rapid transit system, and SBS (Singapore Bus Services) for the buses. They are controlled by the Land Transport Authority (LTA) and by the Public Transport Council (PTC), a public body independent from the government and the LTA. Each operator has a permanent monopoly of its own area. Operators are completely free to decide on the details of their routes and timetables, ensuring 7 million public transport journeys a day, of which 3.6 million by bus, 2.8 million by subway, and 1 million by taxi. The 28,000 taxis in Singapore are in fact considered as public transportation. We will come back to the future challenges facing this city featuring exponential urban growth and an ambition to stand up to private cars.

Generally, TOAs have a key mission to organize and plan public transport, without jurisdiction over other modes of transport, such as railways or roads. London is an exception to the European governance model, since the city's AOT has wide-reaching jurisdictions, including management of the road network and railways, which were formerly run by the British state. Transport in the city, which is mostly managed by the Transport for London network, comes under the jurisdiction of a regional assembly and the Mayor of London.

Transport for London controls most public transportation, including the underground, Docklands Light Railway, buses, trams, and congestion charges, but has no power over railway services directly managed by Greater London. As pointed out by Virlouvet and Fatras (2018) in their book on the organization of transport in Greater London, "*The metropolis of London suffers from an overstretched network and has difficulties carrying out major infrastructure projects to relieve congestion because of financing difficulties and governance issues. Like other major cities in the world, London will have to get used to new mobility modes and rework its organization to accompany the shift*".

[2] Evaluation carried out on the basis of the prices paid by the users (tickets and subscriptions) and of the journeys-kilometers made.

The case of Tokyo is interesting because it illustrates the other extreme of the aforementioned governance models. In fact, the city's transport system runs highly efficiently without any kind of TOA. Tokyo is often singled out for the remarkable service quality of its transportation (comfort and punctuality), despite the absence of operating contracts and incentive measures. Does the competition between numerous operators collecting particularly high revenues ensure efficiency and better management? For historical reasons and thanks to an established diversification of their income sources, operators rely on the intensity of flows on their networks. This highly specific situation is mostly observed in Asian towns.

This first, non-exhaustive examination of types of transport governance in different cities in the world illustrates the diversity of the models chosen and political approaches that are partly connected to local situations. The crucial question is now centered on the economic, financial, and environmental challenges of these different means of governance.

10.3 Challenges Concerning This New Transport Governance

Transport modes and infrastructures have always been key vectors in modernizing communities. Today, public transport and new mobility projects are real drivers of sustainable development in urban metropolises. Below, we take a look at the economic, financial, and environmental challenges.

10.3.1 Economic and Financial Challenges

Most TOAs have wide jurisdictions because they determine a strategic transport development plan. To achieve this, they have the power to make financial choices corresponding to the implementation of the development plan.

Regarding the region of Montreal, the TOA has authority to act on several modes of transport and propose integrated solutions. It has the responsibility to draw up a pricing framework, finance public transport services, and develop carsharing and active transportation solutions. The operation of services is entrusted to STM (*Société des Transports de Montréal*) and the three transport companies that come under a service contract with the authority. One of the challenges for the metropolis of Montreal is to achieve an ambitious target to "*develop an integrated and attractive public transport ecosystem*".

Pricing remains a key challenge for these megacities. In London, for example, the decrease in state funding for transportation has generated a constant increase in tariffs. Transportation is very expensive for users, with no improvements in comfort because of the constant pressure to extend and maintain the network.

Pricing situations range greatly from one metropolis to another for a number of reasons. In the case of Tokyo, for instance, urbanization is compact and heavily reliant on railways, which encourages high public transport usage, including in peri-urban areas, then the TOA can collect substantial revenues that cover most operating expenses. The Tokyo network provides a high-quality service to its users, including punctuality, which is one of the best service criteria. The three main companies are Japan Rail, Tokyo Metro, and Toei Subway & Bus. The specific feature of this network is that diverse companies operate different lines but share the same platforms, rails, and sometimes even trains.

However, in Tokyo, journeys are relatively expensive: in 2020, 900 yen (7.30 euros) for a 24-h subway ticket. The price of a journey is always proportional to the distance traveled. Most Japanese users take monthly passes that reduce the total cost of transport; and over the last 20 years, passengers have had the opportunity of using digital tickets, symbolizing a city that has always been one step ahead in innovation.

In the metropolis of Lyon, which has an extensive and diverse transport system, the share paid by users is no more than one-third of total revenues, resulting in relatively cheap tickets (in 2020, 4.90 euros for a 24-h "Liberté" ticket usable on all types of transport). Most of the revenues come from local authorities (20%) and mobility taxes paid by companies (39%) (SYTRAL, 2020). Most of the time, local authorities make up the majority of additional financing. In France, when income from fares falls far short of covering expenditure, the deficit is made up by the state or the regions.

This situation is the case in Singapore, where the state budget for public transport is structurally loss-making. What are the reasons for this? According to users, it is relatively easy and inexpensive to travel in the city center using public transport, with the subway connecting the airport and most regions on the island. So why do Singaporeans show such little interest in taking public transport? The reason is mainly cultural. Inhabitants of Singapore prefer to drive private cars despite state taxes. Cars are taxed at least 100% of their market value, in addition to which owners are obliged to obtain an eligibility certificate; the purchase of this kind of license is around 50,000 Singapore dollars (31,000 euros). Nevertheless, in Singapore, cars are a symbol of social status, freedom, and personal comfort.

In Lyon, the metropolis has opted for a Program of Economic Development (PED) to create social cohesion with an inclusive territorial offer regarding transportation (2016–2021) (Métropole de Lyon, 2016). This aspect of the policy, pursued over the last four years by Sytral, is noteworthy because it has led to making choices in modes of travel. The objective is to find a balance between localities by connecting the different activity hubs with residential areas. The TOA thus participates in planning Lyon's urban area and the inter-urban area of the Rhône region.

In 2015, the network extended to take in eight municipalities east of Lyon, served by four regular Rhône bus lines, coupled with the creation of a service to Lyon-Saint-Exupéry airport. This new transport development contributes to economic development and creates jobs. Similarly, the main industrial areas of Lyon's metropolitan area are now covered by a bus network. The advantage is that home-to-work car journeys are replaced by reliable, less costly public transportation. This policy is regularly evaluated to monitor the transport options available in terms of services, timetables, journeys, and pricing. Sytral remains the contracting authority but delegates the operation of networks to companies through public service delegations, the biggest being Keolis Lyon.

In Geneva, the main operator, *Transports Publics Genevois* (TPG), currently runs the tram and trolleybus lines in the city, the 64 bus lines, and the night bus network Noctambus. The price of a 60-min ticket is 3 CHF (2.78 euros), which does not make it particularly cheap for public transport journeys. The study carried out entitled "*Ce que coûtent et ce que rapportent les transports publics genevois*" [What Genevan public transport costs and earns] (Ravalet et al., 2019) shows that "*the profits generated by TPG are greater than the public money spent*".

The methodological approach of this study is new and pertinent. The method consists in evaluating the profitability on a societal level and then giving a monetary equivalent to this societal impact. The main parameters include: reduced place of cars in urban areas, better air quality by decreasing CO_2 emissions, fewer accidents, less noise, etc. These "monetized" criteria mainly concern public health and the environment (this monetization of local external costs are also discussed in Chap. 4). This kind of overall approach to positive externalities appears to be fairer and more balanced because it integrates all statistics relating to a territory. It shows that a financial transport strategy can "*earn more than its initial investment*". As such, "*1 million CHF of public contribution to TPG brings in 1.18 million CHF*" which can be divided into 25% in purchasing power gain, 40% in time saving, 25% in land valuation, and 10% in health, climate, and environmental benefits (Mobil'Homme, 2019).

The question of urbanism and land planning is indissociable from a strategic transport plan. Numerous studies in France show that the cost of home-to-work journeys represents 18% of the population's income, which is not negligible (Thébert, 2019). When megacities expand, so does the phenomenon of urban sprawl, with residents opting to live far from the city center in areas that often have little or no bus and rail access. Thus, the use of private cars becomes inevitable and creates bottlenecks at the entrance to the urban centers.

These inhabitants living in suburban areas are subjected to a *double penalty*. The amount they spend on travel – often with two vehicles per household – increases year on year in cost of vehicle usage (gas, maintenance, insurance), eating into their income. At the same time, they suffer from real state devaluation due to the lack of easy access to public transport offerings. This trend is apparent throughout Europe, where the connection between property value and land planning in terms of transport is clearly shown. The better the transport availability, the higher the cost of housing, which thereby validates once more the common cliché used by real-estate experts when referring to the three most important factors in determining the desirability of a property: "location, location, location".

10.3.2 Environmental Challenges: Towards Ecological Transition

The world's megacities have been pursuing energy transition strategies for a number of years in order to develop a sustainable urban model. For most of them, this involves promoting decarbonized transport, both private and public, and new mobility practices (walking, cycling, car-sharing, etc.).

In France, since 2018, the national strategy for ecological transition (2015–2020 plan) anticipates taking into account innovation avenues relating to transport systems with the aim of reducing their energy consumption and negative impacts on the environment: fuel-efficient, non-polluting cars; innovative, energy-saving road infrastructures; and smart transport systems and services.

The Law on Mobility Orientation (*Loi d'Orientation sur la Mobilité* – LOM) voted on September 5, 2019 (LOM, 2019), will both validate these strategies and implement a deep-seated shift in the French mobility policy. In sum, the "*right to mobility is a Republican promise*", translated by a concrete improvement in everyday journeys for all citizens all over the country. Major cities need to embark on a transition towards less-polluting mobility. This involves respecting the 2050 carbon neutrality target written into the law, in line with the Climate Plan, with a clear trajectory: −37.5% CO_2 emissions by 2030 and a prohibition to sell cars that use fossil fuels by 2040.

A conversion bonus has also been established along with the possibility of charging electric vehicles everywhere by creating five times more charging stations by 2022: making this equipment obligatory in some car parks, creating the right to a charging point, and halving installation costs. The creation of low-emission zones to make air more breathable will allow local authorities to restrict circulation to the least-polluting vehicles based on their own criteria. To date, 23 local authorities, concerning more than 17 million inhabitants, have taken up this approach. Another strong point of the LOM is the acceleration in the development of innovative mobility solutions, including the circulation of autonomous shuttles by 2020.

Other large cities have also begun the ecological transition, but by making other choices. London for instance, is aiming to improve air quality with the creation of congestion charges and low-emission zones and the development of renewable energy. Singapore has opted to set up a dynamic toll system to limit congestion in the city. The objective of the TOA is to limit journey times to 45 min within the town center. The population of Singapore could reach 10.5 million by 2030, and this demographic growth is incompatible with the development of automobiles, calling for innovative transport solutions, such as carsharing, micro-mobility, and autonomous shuttles.

The city of Helsinki, with a population of 1.1 million, has ambitious carbon-neutrality objectives and has equipped itself with an efficient Mobility-as-a-Service (MaaS) tool called Whim. The principle of MaaS is to combine different transport services in the same mobility package. This integrated system includes information, reservation, and purchase of the chosen transport ticket. Users have personal accounts to manage their purchases after defining their preferences and profile (see Chap. 9 for more details on MaaS).

A study carried out by (Dubois et al., 2019) on the MaaS experience in Helsinki, Vienna, and Hanover shows the numerous benefits anticipated by local authorities and users, and how this practice works towards a better ecological transition. The main reason is that the Whim application is a truly integrated mobility services system. With Whim, users can make reservations and payments, using an application, for all public transport (bus, tram, subway), as well as bike-sharing systems, taxis, carsharing, and rental systems. The study shows that the objective of MaaS is to encourage a modal shift by providing all the necessary information on alternatives to using a private car.

MaaS aims at making other shared mobility services easier and more comfortable. What is the impact of MaaS usage on passenger behavior? An evaluation of the Whim service produced by MaaS shows that Whim users "*take public transport and taxis more frequently than inhabitants do on average*". In Vienna, the evaluation of this same project concludes that users have changed their mobility behavior, with a 21% reduction in car use by those questioned, and a 26% increase in journeys by public transport (Hartikainen et al., 2019). For an in-depth analysis on user-centered design of mobility solutions, see Chap. 6.

But the key to the success of the MaaS application for everyone everywhere is that it fully participates in developing sustainable mobility and effectively accompanies ecological transition policies through the choice of alternative solutions to solo driving.

In Luxembourg, due to the health crisis, the Ministry of Transport has organized digital presentations via Live Stream on the rapid tram connecting Luxembourg City and the South region and its multimodal context (Ville de Luxembourg, 2020). For the first time, citizens have been invited to ask questions live about how this new fast tram operates. The experience is likely to be repeated because its success has encouraged the Ministry of Transport to organize a questions and answers session for citizens.

In Tokyo, in addition to choosing a smart city (Leprêtre, 2017), environmental choices are related to energy choices and a history of local authorities opting to use renewable energies and set up real ecosystems, like in Fujino. Located one and a half hours from Tokyo in the Kanagawa prefecture, this town of 10,000 inhabitants takes a global approach to mobility and lifestyle. It was officially the first Japanese town to pioneer the ecological transition and the one hundredth in the world. Following the Fukushima crisis, residents aware of energy issues developed their own local economy with specific methods using a maximum of local resources. Their food production approach is inspired by permaculture (in fact the Permaculture Centre in Japan is in Fujino), their electricity is produced from solar power and, to travel around, residents take either the train, or hybrid or gas-powered vehicles. For the project leader, Hide Enomoto, the idea is "*to get back our own self-sufficiency in the face of a system on which we have become too dependent*" (Enomoto, 2017).

This unusual story is reflected by other major cities in Japan that are promoting renewable energy sources, like hydrogen, solar, and wind power, which represented

18% of total energy in 2019. These new energies are part of a global plan implemented by Japan's Energy METI (2015–2030) to maximize the energy transition. In Japan, 72.5% of traffic is done by rail, and thus is mainly electric, including in megacities like Tokyo. The issue of the sustainability of urban mobility through transport choices is being successfully tackled.

10.4 From Private Innovation to New Public Transport Mobility

In the transport sector, innovation has always been carried out on one side by individual transportation, and on the other by public transportation, with trains, the combustion engine, then the electric car, and autonomous cars and shuttles. These two visions of transport now tend to compete with each other in cities because individual mobility solutions no longer have their place, except for bicycles and micromobility (e.g., electric scooters).

10.4.1 Innovative Solutions for Private and Individual Mobility

Easing congestion and reducing pollution from major cities do not mean increasing the number of private electric cars, which would only partially solve the problem. A high volume of individual cars at rush hour leads to urban congestion and time-loss, which need to be avoided. Carsharing is one of the solutions chosen in Singapore. According to a study by the Car Sharing Association (Ming, 2016), one shared car could remove 14 private cars from the road. That same year, in December 2017, an electric carsharing service was set up in Singapore called Blue SG, a subsidiary of the French group Bolloré. Nevertheless, carsharing will not eliminate the daily bottlenecks in the megacity, which has had to look for other innovative solutions.

The opposition of the city of Singapore to the massive entry of Tesla in 2020 illustrates this same determination, and even a certain hostility towards individual cars. Tesla is still awaiting authorization to deploy its superchargers, since 52% of Singaporeans declare that they do not intend to buy an electric car in the absence of sufficient charging stations.

Lastly, a new debate is under way. For Singapore's minister of the environment, hydrogen is a much better option to combat CO_2 emissions (PDD, 2020). It is considered that producing batteries for electric cars and recycling them at the end of life constitutes a significant carbon footprint. However, the debate about energy (electric or hydrogen) does not resolve the issue of traffic regulation and the most suitable mode of transport.

Could Autonomous Vehicles (AV) be the ideal solution for traveling around urban areas? This new technology conforms to a universal standard (SAE, 2016). In the 2000s, this disruptive innovation generated a new business model and a new approach towards cities, mobility use-cases, and users (Attias, 2017).

Autonomous vehicles cannot operate without an organized ecosystem like a smart city. In Singapore, artificial intelligence innovations are under way. These innovative computer technologies are able to process vast quantities of information and are crucial for the future operation of driverless car systems. However, cities cannot expand endlessly and their road networks are somewhat limited to a maximum quantity of vehicles. In addition, some studies point to the risk of over-intensive use of AVs: easy access to autonomous car services could generate an exponential multiplication of journeys, which would provoke total traffic saturation in cities with geographic and urban configurations similar to Singapore.

In the USA, the question is different for geographical, socio-cultural, and regulatory reasons, because the configuration of road and urban infrastructures in the country is very different from everywhere else. Major cities sprawl for miles (e.g., Los Angeles, which stretches 80 km north-south) and feature immense road networks. As a result, starting in 2016, some states like California and Arizona have accepted the circulation of totally autonomous vehicles on their territories. In Arizona, autonomous vehicles can be tried out without prior authorization (a permit or license). In 2019, the Californian department of transportation published statistics on the circulation of autonomous vehicles from 2017 to 2018: driverless cars from the company Waymo (designers of the Google Car) had covered 1.2 million miles (almost 2 million kilometers) on California roads.

Autonomous vehicles have been the object of abundant literature over the last ten years [Auer, Feese, & Lockwood, 2016; Gandia et al., 2018; Greenblatt & Shaheen, 2015; MTE, 2019; US Department of Transportation, 2017), and continue to examine TOAs and traditional car manufacturers around the world. The latter have moved into this disruptive innovation not necessarily by choice, as pointed out by Jullien (2014, 2015), but more through fear of competition and losing the race against other companies in sectors ranging from IT to transport and telecommunications, like Google, Apple, and Uber.

The US innovation culture led by research centers, universities, and start-ups strongly contributed to the emergence in the 2010s of radical innovations in artificial intelligence, robotization, and digitalization of communication supports. What emerges as key is that AVs cannot really circulate without a suitable ecosystem like a smart city and, in the long run, a communication system between vehicles.

The difference in the US approach to the deployment of AVs compared to the rest of the world is also related to legislation and regulation issues. As pointed out by Clément-Fontaine (2018), two major legal questions arise in Europe: the use of personal data (which constitute an invasion of privacy), accidents that cause physical or material damage and raise the question of responsibility. In the case of AVs, "*if there is a delegation to drive on public roads, the identification of the responsible party and thus, compensation of the victims, are subject to debate, in particular since this technology is undergoing rapid changes*". The Vienna Convention, which defines international rules for road traffic, stipulates that drivers must always remain in control of their vehicles, but since 2016 authorizes automated systems "*provided that they can be overridden or switched off by the driver*".

On the other side of the Atlantic, however, in 2018, the US House of Representatives approved a law devised to facilitate the deployment of autonomous vehicles by preventing states from imposing over-restrictive regulations. Arizona has increased incentives to test out self-driving vehicles on its roads to compete with California, which has stricter regulations on test drives. For further details on regulations and public policies regarding AVs, see Chaps. 2 and 3.

10.4.2 Autonomous Vehicles: An Innovative, Collective, and Public Solution

Individual transport or public transport? This question is at the heart of the current transportation issues facing the world's major cities. Increasingly, innovation is not concentrated on cars and individual transportation, but rather on collective transport (as shown in Chap. 1).

While the world's automobile industry is pursuing its incremental innovations, in the public sphere, radical innovations are emerging supported by local public powers. Personal air vehicles, suspended cabins halfway between a cable car and a sky train, driverless shuttles: what will tomorrow's cities look like? Which stakeholders are prepared to invest in these innovative mobilities? This question finds an adapted, innovative response resolutely turned towards the future in the emergence of a new collective mode of transport: the autonomous shuttle.

In Europe, in 2018, the European Commission launched calls for tender on EU programs (H2020) with the objective of finding innovative solutions in collective public transport. The response of the AVENUE program (*Autonomous Vehicles to Evolve in New Urban Experience*), which runs until 2022, is to experiment and deploy autonomous shuttles in four European towns: Lyon, Geneva, Luxembourg, and Copenhagen (AVENUE, 2018).

The program's ambition is to create innovative services to satisfy all user needs, propose technological improvements, implement shared on-demand transport, and evaluate the socio-economic impact in cities: in a nutshell, build a future urban ecosystem. Sixteen European partners, including universities, research centers, and public operators, and in particular the French autonomous shuttle manufacturer Navya, are participating in the project which has a budget of 20 million euros.

One of the key objectives of the program is to demonstrate that Europe can become a leader in this domain by changing European regulations (Vienna Convention) that still require the presence of an operator (safety driver) on board the shuttles. Nevertheless, it is important to remember that these shuttles complement existing public transport and can in no circumstances substitute the public transport system.

On the field, positive feedback from users of autonomous shuttles provides an incentive to think about taking this experimentation further and transforming it into a permanent, reliable form of transportation adapted to demand. Details on this experimental program, which has been running for three years, are provided in Chap. 5.

10.4.3 Shared Public Transport on Demand

The choice of collective, ecological, shared transportation already comes across as the optimum solution. However, in the light of our experience on the AVENUE program, it requires the installation of small or medium-sized shuttles or minibuses.

Why is this choice pertinent? Firstly, these Navya-type vehicles are more technologically efficient, electric, equipped with sensors that detect any changes on the roadway, and can immediately adapt to risk situations, e.g., a pedestrian running across the road in front of the shuttle, a cyclist moving out of the bike lane, a car not giving way, etc. This reliability of passenger security is a considerable asset. Speeds are reduced to a maximum of 25 km/h, which corresponds to the speed limits in city centers (e.g., 30 km/h in Lyon).

The second reason behind the quality of this type of transport is that the number of passengers is no more than fifteen. Regular journeys to work, for medical visits, or leisure can create user communities in these shuttles comprising passengers who enjoy everyday moments together and not just time spent traveling. This is the case for people making regular trips for medical care who meet others going through similar experiences on their journeys.

A third reason for this choice lies in the flexibility of this kind of shuttle, which can run 24-7 and, in particular, can meet the demands of all of its users. During the day, the shuttle can be used to transport specific school groups, employees, tourists during off-peak hours, and older people and at night for night workers or young people looking for a safe way to get home after a night out.

The main advantages of these vehicles are that they do not take up much room on the road, they stop on request, and they have no driver, which will lead to considerable long-term savings (as shown by the economic assessment tool proposed on Chap. 4). Shuttles would be piloted from a permanent operating center to monitor and control the operability of vehicles.

Other solutions have been put forward by young start-ups like Supraways, a Lyon-based company created in 2015 that designs, develops, and commercializes a rapid, upmarket public transport network featuring suspended cabins that travel above public areas and traffic. These cabins can transport goods or carry seven to nine passengers and adapt their volume and speed to meet demand. The founder, C. Escala, describes his project as:

> *A revolutionary urban transport concept, developed in close collaboration with US and Swedish PRT (Personal Rapid Transit) experts, which will both largely resolve the complex equation of space and congestion and pollution issues. Urban sprawl is no longer an option*

for cities, on the contrary, we need to optimize the public space! So we had to think up a system that benefits the users, the locality, and the operator. The Supraways model requires little or no public financing because we are aiming at intrinsic profitability. It could be open to private investment through concession agreements or private-public partnerships which are easier to implement. We chose the name Supraways because it conveys the idea of moving through the air to free up the space on the ground, which is increasingly saturated, and create a second, more free-flowing territory that generates value (Supraways, 2020).

This new approach to future mobility has much in common with autonomous shuttles: the choice of a high-performing technology, with an accent on public transport on demand that complements transportation currently available, and a target of long-term profitability.

To conclude on the key challenges of these innovations and their connection with urban areas, Fig. 10.1. displays the diagram produced by Supraways comparing the old urban world with that of the future.

However, as our publication goes to print, an unprecedented health crisis generating disruption is raising questions about the way we move around and could trigger new transport models. The dreaded promiscuity of subways, trains, and buses has caused some users to turn back to private cars (30% increase during the second half of 2020). Should this trend be analyzed as temporary? F. Bayrou, High Commissioner for Planning in France, is examining our current situation and has reflected on "*Exchange, which is at the root of our economic growth and the foundation of our social relations*" – as can be experienced in public transport – *could it now constitute a threat in itself?*" (Bayrou, 2020).

The health crisis is challenging both governments and the population, and it is highlighting the way we produce, consume, and move around. It is accelerating the extensive use of digital solutions like teleworking, teleteaching, and

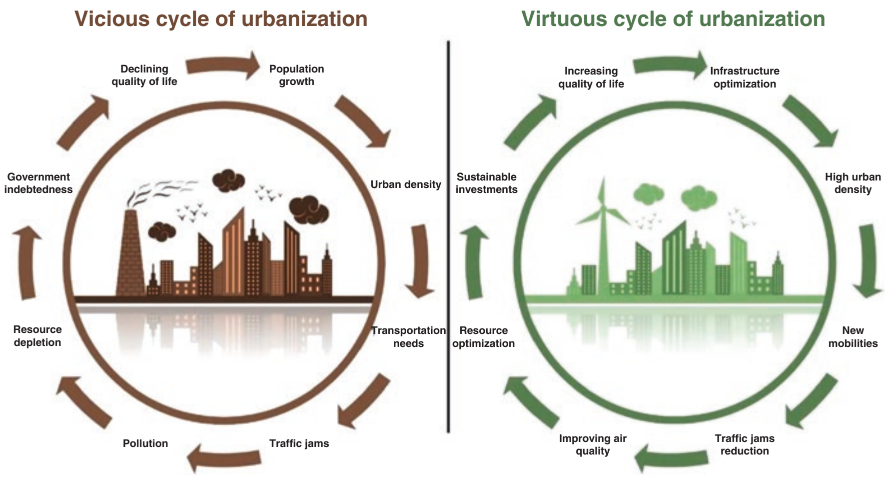


Fig. 10.1 The vicious and virtuous cycles of urbanization. (Source: adapted from supraways.com)

tele-administration and already creating new means of socio-professional relationships and, tomorrow, travel choices.

10.5 Conclusion

The governance of public transport in the world produces contrasting situations from one metropolis to another, depending on their institutional, cultural, and geographic features. However, the future seems to be taking shape with an agile governance that is capable of coordinating mobility choices with infrastructure choices.

Interaction with users, in particular in shared mobilities, means that their needs can be better targeted. On-demand public transport is part of the future key challenges facing cities, and more widely, is becoming a challenge for society. To move around is to adopt a way of life and social relations. The unusual period marked by the COVID-19 health crisis may encourage citizens to get more involved in mobility projects.

Until now, cities have focused their efforts on information and sometimes consultation, yet it is now imperative to involve users and make them responsible in order to maintain social cohesion. This public transport revolution is a mobility revolution through the use of new technologies. It creates new relationships between citizen-users and encourages innovative mobility solutions that are transforming cities into digital cities.

These new modes of governance and mobility certainly pave the way for robomobility Autonomous vehicles are therefore already in a robomobility perspective by offering serene, ecological, and sustainable mobility. Tomorrow, we will be users, passengers connected to all these forms of mobility, including on-demand mobility. Robomobility offers an extraordinary world of possibilities and, above all, will enable everyone to live a more comfortable life on public transport.

Acknowledgments This research has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769033 (AVENUE project).

References

Agence de Transition Ecologique [ADEME]. (2019). La mobilité décarbonée, quels vecteurs énergétiques pour une mobilité décarbonée? Enjeux territoriaux et sociaux de la mobilité, XX° Congrès de l'OSE (Optimisation des Systèmes Energétiques), CMA Mines-ParisTech, Sofia-Antipolis, 20.

Attias, D. (2017). *The automobile revolution: Towards a new electro mobility paradigm.* Springer

Auer, A., Feese, S., & Lockwood, S. (2016). History of intelligent transportation systems. The National Academies of Sciences, Engineering, Medice. Study report. Available at: https://trid.trb.org/view/1418799

Auvinen, H., & Tuominen, A. (2014). Future Transport Systems: Long-TermVisions and Socio-Technical Transitions. *European Transport Research Review, 6*(3), 343–354.
Bayrou F. (2020). Et si la Covid durait ? Opening note from October 28, 2020 of the French Haut-Commissariat au Plan. Available at: https://www.gouvernement.fr/et-si-la-covid-durait-le-haut-commissaire-au-plan-lance-le-debat
Clément-Fontaine, M. (2018). Les mutations du droit relatives aux véhicules autonomes. In *Les Mobilités à la lumière des sciences sociales*, MSH Paris-Saclay Editions (pp. 49–53).
Courmont, A., & Le Galès, P. (2019). *Gouverner la ville numérique*. Paris: PUF.
Dubois, D., Aliaga, A., Bonnet, G., Delamarre, E., Chevereau, L., and Clément-Werny, C. (2019). MaaS in Europe: Lessons from the Helsinki, Vienna and Hanover experiments. Study report by CEREMA. Available at: https://www.cerema.fr/system/files/documents/2020/04/cerema_parangonnage_maas_synthesis_eng.pdf
Enomoto, H. (2017). Fujino, la ville japonaise en transition écologique, News article. Available at: https://japanization.org/fujino-ville-japonaise-modele-de-la-transition-ecologique/
Gandia, R. M., Antonialli, F., Cavazza, B. H., Neto, A. M., Lima, D. A. D., Sugano, J. Y., et al. (2018). Autonomous vehicles: Scientometric and bibliometric review. *Transport Reviews, 38*, 1–20.
Geoffron, P. (2017). Smart cities and smart mobilities. In D. Attias (Ed.), *The automobile revolution: Towards a new electro mobility paradigm*. Cham, Switzerland: Springer.
Greenblatt, J. B., & Shaheen, S. (2015). Automated vehicles, on-demand mobility and environmental impacts. *Current Sustainable Renewable Energy Reports, 2*, 74–81.
Hartikainen, A., Pitkänen, J., Riihelä, A., Räsänen, J., Sacs, I., Sirkiä, A., and Uteng, A. (2019). Whimpact: Insights from the world's first moblity-as-a-service system. Study report by Ramboll. Available at: https://ramboll.com/-/media/files/rfi/publications/Ramboll_whimpact-2019
Jakson T. (2019). Prosperity without growth? The transition to a sustainable economy. Available at: https://research-repository.st-andrews.ac.uk/bitstream/handle/10023/2163/sdc-2009-pwg.pdf?seq
Jullien, B. (2014). Construction automobile: réinventer le modèle industriel. *Place Publique, 29*, 9–14.
Jullien, B. (2015). The Case of French Car Manufacturing. In: Jetin Br. *Global automobile demand, vol. 1: Major trends in mature economies*, London, Palgrave-MacMillan, p. 72-104.
Kemmeter, F. (2020). Singapore without cars: Between dream and reality. Mediarail.be. Available at: https://mediarail.wordpress.com/singapore-without-cars-between-dream-and-reality/
Laurent, S., Prédali, F., Cariou, C., & Wolf, M. (2019). Comparaison des autorités organisatrices des transports à Londres, Tokyo, Singapour et Helsinki, Study report by Institut Paris Région. Available at: https://www.institutparisregion.fr/fileadmin/NewEtudes/000pack2/Etude_2078/Comparaison_AO_IAU_20191010_VF.pdf
Leprêtre, N. (2017). Les villes « intelligentes » au Japon. Available at: http://geoconfluences.ens-lyon.fr/informations-scientifiques/dossiers-regionaux/japon/corpus-documentaires/villes-intelligentes
Litman, T. (2020). Evaluating public transit benefits and costs in Victoria. Transport Policy Institute. Available at www.vtpi.org
Loi N° 2019-1428, Orientations des Mobilités (LOM), published on 24/12/2019 at the Journal Officiel France.
Lyan, M. (2020). A Lyon, le président EELV Bruno Bernard prend aussi les rênes du Sytral. In *La Tribune*. Available at: https://acteursdeleconomie.latribune.fr/territoire/politique/2020-09-07/bruno-bernard-prend-aussi-les-renes-du-sytral-856547.html
Marchal, M. (2013). Projet Montréal attaque la vision de Denis Coderre sur les transports. In *Journal Metro*. Available at: https://journalmetro.com/actualites/montreal/391169/projet-montreal-attaque-la-vision-de-denis-coderre-sur-les-transports/
Meijer, A., & Bolívar, M. P. R. (2016). La gouvernance des villes intelligentes. Analyse de la littérature sur la gouvernance urbaine intelligente. *Revue Internationale des Sciences Administratives, 82*(2), 417–435.

Métropole de Lyon. (2016). Economic Development Program (2016–2021). Available at: https://www.metropolis.org/sites/default/files/2019-01/Lyon%20Economic%20Development%20Programme%202016-2021.pdf

Ming, T. E. (2016). Singapore to launch electric vehicle car-sharing programme in 2017. News article. Available at: https://www.todayonline.com/singapore/singapore-launch-all-electric-vehicle-car-sharing-programme-2017

Ministère de la Transition Energétique [MTE]. (2019). Développement des voitures autonomes, Orientations stratégiques pour l'action publique, Study report. Available at: https://www.ecologie.gouv.fr/sites/default/files/90p%20VDEF.pdf

Pinson, G. (2009). *Gouverner la ville par projet: urbanisme et gouvernance des villes européennes*. Paris: Presse des Sciences politiques.

Project AVENUE. (2018). Objectives of Avenue project. Available at: https://h2020-avenue.eu/objectives/

Ravalet, E., De Lapparent, M., Kaufmann, V., & Klein, O. (2019). *Ce que coûtent et ce que rapportent les transports publics genevois*. In *Study report by Mobil'homme*. Available at: https://www.tpg.ch/sites/default/files/2019-11/2019%20Mobil%27homme%20Etude%20tpg.pdf

Razemon, O. (2014). Métro, bus, taxis, voirie, le modèle de Singapour est-il exportable ? In *Le Monde*. Available at: https://www.lemonde.fr/blog/transports/2014/09/26/metro-bus-taxis-voirie-le-modele-de-singapour-est-il-exportable/

Society of Automative Engineers [SAE]. (2016). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016_201609, Available at: https://www.sae.org/standards/content/j3016_201609/

Supraways. (2020). Company's website. Available at: http://www.supraways.com

Syndicat mixte des Transports por le Rhône et l'Agglomération Lyonnaise [SYTRAL]. (2020). *Ressources*, 2020. Available at: http://www.sytral.fr/168-ressources-2019.htm

Thébert, M. (2019). Urbanisme et mobilité. De nouvelles pistes pour l'action, Xavier Desjardins, Paris: Éditions de la Sorbonne, 2017. *Flux, 115*(1), 79–80.

US Department of Transportation. (2017). Automated Driving Systems 2.0: A Vision of Safety. Study report by NHTSA. Available at: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

Van Audenhove Fr.-J., Dauby, L., Korniichuck, O., & Pouraix, J. (2014). The Future of Urban Mobility 2.0: Imperatives to Shape Extended Mobility Ecosystems of Tomorrow, Arthur D. Little. Available at: https://www.adlittle.com/sites/default/files/viewpoints/2014_ADL_UITP_Future_of_Urban_Mobility_2_0_Full_study.pdf

Ville de Luxembourg. (2020). Présentations digitales sur la réorganisation et le nouveau réseau de bus RGTR. Livestream presentation of 26 november 2020. Available at: https://www.vdl.lu/fr/actualites/presentations-digitales-sur-la-reorganisation-et-le-nouveau-reseau-de-bus-rgtr

Virlouvet, P., & Fatras, C. (2018). L'organisation des transports dans la métropole de Londres : un historique de ses atouts et de ses difficultés. *Annales des Mines - Réalités Industrielles*, 60–64. Available at: https://www.cairn.info/revue-realites-industrielles.htm

Conclusion

The Urban Public Transport Revolution: Paradigm Shift?

Sylvie Mira-Bonnardel, Fabio Antonialli, and Danielle Attias
e-mail: sylvie.mira-bonnardel@ec-lyon.fr;
fabio.antonialli@ec-lyon.fr;
danielle.attias@ecp.fr

Within its ten chapters, the book shows how politics, regulation, uses, and service innovation are deeply changing the landscape of urban mobility, spurring a genuine paradigm shift that paves the way for a new public transport paradigm. In this paradigm shift, the arrival of autonomous vehicles, resumed here by the neologism robomobility, represents a major cause of disruption. Robomobility obliges public transport operators as well as policymakers to think differently and build a new philosophical, theoretical, and operational framework for urban mobility.

Experiencing such a paradigm shift makes the whole community think differently and build this new philosophical, theoretical, and operational framework whose foundations are presented in the different chapters of the book.

The paradigm shift marking public transport is driven by robomobility and is embedded in a systemic movement. Indeed, along this shift, a holistic view is not enough to understand the "ins and outs" of it, since this shift comes with the emergence of a new ecosystem. Stakeholders of this ecosystem are struggling to settle on a dominant design for a smart mobility, which is closely linked to the economic and social impact of its deployment, which conversely makes business models, social trends, as well as regulation evolve in a helicoidal movement we tried to picture in this book along its ten chapters.

During the last decade, the shift has been mostly carried by vehicle technology in parallel with societal changes. Although automotive technology and user behavior may evolve in the next few years, they are not the major engines anymore for the

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9

new mobility paradigm. The main driver for the development of robomobility should be its economic impact, a driver all the more important as the economic context will get worse, as the 2020 health crisis is going quite surely to be doubled with an economic crisis.

Indeed, the book shows how robomobility helps to reconfigure business models for public transport from a fixed and rigid mobility offer to an on-demand flexible mobility anchored within the Mobility-as-a-Service (MaaS) framework. The experience of the Belle-Idée district in Geneva (AVENUE, 2020), anticipates this transition towards on-demand autonomous public transport. Users request an autonomous shuttle service via their cell phones for their journey from a scheduled departure point to a destination. These technology-enabled experiences are well received by users not only by convenience and comfort but by reducing their waiting times. This trend plays an essential role for the development of sustainable urban mobility in megalopolis, more acutely in emerging countries where public transport is still under development.

Besides, the integration of driverless, connected, collective vehicles into the public transport network brings mobility into the core of the Internet of Things (IoT). With each vehicle becoming a connected device, it allows the implementation of a customizable, and affordable fleet management system to monitor a large driverless fleet, thereby increasing traffic fluidity and reducing congestion and pollution (Cagáňová & Horňáková, 2018).

Without including reduction of drivers' wages, the uses of relevant evaluation tools demonstrate that robomobility brings a better financial balance with higher efficiency and cost reduction. This is reinforced by the tactical implementation of V2X (Vehicle-to-Everything), a systemic approach that enables vehicles to communicate with the environment, aiming to make autonomous vehicles safer, smarter, more economical, and convenient.

Although IoT and connected cities are already a reality, the protection of personal data is still a problem and is the subject of many discussions. The future of autonomous urban transport depends on the support of a robust system of regulations, monitoring, and data protection. Furthermore, the economic strength of robomobility is carried via big data management, a central issue if appropriately treated may reveal economic opportunities. Thereby, one of the most appropriate solutions to safeguard all these data is the integration of blockchain technology.

Blockchain is a technological breakthrough, and new decentralized database technology that helps to increase collaboration, the sharing of trusted information and efficiency, it reduces costs and risks while potentially forging new business models in the transportation space for the years to come. Some of the key features of blockchain include consensus, immutability, provenance, finality, a single version of the truth, customizable transparency, and decentralization.

With the implementation of blockchain technologies and the use of a common clearing and settlement currency within the system, commuters will now be able to buy transit tickets from the start point to the destination in a far simpler and time effective manner. For someone who wants to take rides on multiple train lines, hop on a bus and then take a ride on a bike for the last few hundred meters, it would require at least four transactions and several visits to ticketing counters or machines, and queue in line multiple times. Now, a blockchain powered platform can provide a one-stop shop for such a purchase, ditching the outdated, inefficient legacy processes and systems. Thus, providing the commuters a superior user experience and saving time and money in the process. The benefits are even more pronounced for inter-city and cross-border travels.

At another socio-economic level, we can imagine multi-purpose autonomous shuttles for multiple types of users. The various scenarios require adaptable, flexible transportation solutions that meet a wide range of personal mobility and parcel delivery needs. Furthermore, robomobility has been reinforced by the current COVID-19 pandemic thanks to this aforementioned flexibility it brings into public transport.

As communities around the world have shifted to more home-based activities, the need to move goods and services without human interaction has become more important than ever, while the need to protect their drivers is of high consideration for logistic companies. Autonomous driving has the potential to fundamentally change the way goods move from warehouse to storefront, meals from restaurants to our front door, and how our packages get from retailers to our mailboxes. While COVID-19 may have slowed consumer purchasing of new vehicles, it has also increased the potential for further adoption of autonomous driving for other needs than moving people.

Autonomous driving has also proved to be essential in the fight against the pandemic, easing the burden of COVID-19 by transporting necessary medical supplies and food to health-care professionals and the public in infected areas and disinfecting hospitals and public surfaces to reduce the spread of coronavirus. In China and some parts of the USA, autonomous vehicles are used to carry out a full range of disinfectant operations and cover the entire surface of a road.

The large-scale deployment of robomobility, combined with online services, user profiling, and dynamic itinerary optimization, will have a snow-ball disruption-effect on today's public transport model. The disappearance of the drivers will allow transport operators to deploy more vehicles and allow vehicles to divert from the predefined itineraries and start offering door-to-door services based on online dynamic reservations and optimization, leading to transit service personalization for people or goods. The absence of a driver should be authorized at a very near future as it has been legislated in December 2020 in France, where a new legislation allows transport operators to remove the safety driver and externalize the control and monitoring of trips to a remote control center (Légifrance, 2020). The first experimentation of this kind is set to take place at Saint-Quentin-en-Yvelines in the Paris region, in March 2021. Thus, the entire public transport ecosystem (policymakers, operators, manufacturers, IT services, platforms, users, etc.) has definitely started to think differently and to build a new philosophical, theoretical, and operational framework for urban mobility and public transport, laying the foundation for a new public transport paradigm.

References

Autonomous Vehicles to Evolve to a New Urban Experience [AVENUE] project. (2020). Green light for the launch of automated vehicles providing an on-demand service at the Belle-Idée site. Available at: https://h2020-avenue.eu/green-light-for-the-launch-of-automated-vehicles-providing%E2%80%A8an-on-demand-service-at-the-belle-idee-site-hug/

Cagáňová, D., & Horňáková, N. (Eds.). (2018). *Mobility internet of things*. Springer, Springer Nature AG, Gewerbestrasse 11, 6330 Cham, Switzerland.

Légifrance. (2020). Décret n° 2020-1495 du 2 décembre 2020 modifiant le décret n° 2018-211 du 28 mars 2018 relatif à l'expérimentation de véhicules à délégation de conduite sur les voies publiques. Available at: https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000042601753

Index

A
Advanced Institutes of Convergence Technology (AICT), 33
Automated vehicles, 56
Autonomous vehicles (AVs)
autonomous shuttle experiments, in France, 40
biliometric analysis, AV policy document methodology, 41, 42
Energy Transition for Green Growth Act (LTECV), 38
Korean AV policies
acceleration phase, 26, 29
planning phase, 26
recognition phase, 25
selection phase, 25, 26
Korean AV policy, 34
Korean government's goals, 29
legal and regulatory framework
Autonomous Vehicles Act, 32–33
Motor Vehicle Management Act, 32
Road Traffic Act, 32
Mobility Orientation Act, 40
PACTE Act, 38, 39
policies for social acceptance, 33
R&D programs, 46
regulation, 52
Autonomous vehicles for collective transport (AVCTs)
autonomous navigation, 6
consumer acceptance and regulatory frameworks, 4
economic impact assessment, 89, 90
first-and last-mile services, 16, 17
fixed route on-demand stops, 12
fixed route with fixed stops, 11
fixed route with flexible detours and on-demand stops, 13
full on-demand door-to-door smart public transport, 14, 15
fundamental research, 88
geofenced flexible gridded routes, 13, 14
human monitoring, 6
incoherent transfers and connections, 17
MaaS mobility paradigm, 15, 16
mixed-traffic conditions, 8
on-demand mobility, 88
on-demand stages for, 10
public urban road transport, 7
road safety, 6
technological development, 88
transportation business model, 6
underserved communities, 17
unnecessary trips, 17, 18
urban centers, 4
worldwide experimentations, 7
Autonomous Vehicles to Evolve to a New Urban Experience project (AVENUE), 87, 108
autonomous vehicles, 110, 111
Copenhagen demonstrator, 122
approval process, 122
assessor role, 122
Nordhavn status complication, 125
test site homologation, 123–125
vehicle homologation, 123
deployment of public transportation, 114
door-to-door services, 128

S. Mira-Bonnardel et al. (eds.), *The Robomobility Revolution of Urban Public Transport*, Transportation Research, Economics and Policy,
https://doi.org/10.1007/978-3-030-72976-9

Autonomous Vehicles to Evolve to a New Urban Experience project (AVENUE) (*cont.*)
fleet orchestration system, 113
Geneva demonstrator, 118–122
application process, 120
test site homologation, 119
TPG Belle-Idee site, 121
vehicle homologation, 119
legal framework, 127
macro-navigation, 113
micro navigation, 113
NAVYA Autonom Shuttle, 112
on-demand mobility, 109–110
overview, 109
passenger services, 116
regulatory frameworks, 114
vehicles certification, 115
vehicles for public transportation, 116
SAE classification, 111
transport service policies, 126–127

B
Barriers and drivers
analyzed business models, 178
business model implementation, 176, 177
BRT, 173

C
CAV technology, 30
City Alternative Transport System, 52
Cooperative intelligent transport systems (C-ITS), 25
Criminal law, 61

D
Demand-Responsive Transit (DRT), 8

E
Economic Assessment of Services with Intelligent Autonomous Vehicles (EASI-AV)
design methodology, 90, 91
economic impact evaluation, 99, 101
fleet size dimensioning, 92
global impact evaluation, 95, 99
limits of, 102
local externalities assessment, 94, 98
service contextualization, 92
structure, 91
TCO evaluation, 93
test pilot in Luxembourg, 95, 97
Energy Transition for Green Growth Act (LTECV), 38
EZ10, 8

F
French Data Protection Authority (CNIL), 57
Future Car Industry Development Strategy, 30, 34

G
GERD Index, 81
Governance of public transport, 193
autonomous vehicles, 205
causes of change, 194
economic and financial challenges, 198, 199
environmental challenges, 201, 202
global situation, 194
Navya-type vehicles, 206
private and individual mobility, 203, 205
shared public transport, 206, 208
TOAs, 195–198

H
Hollande, François, 35

I
Inland Transport Committee (ITC), 54
Innovative mobility systems, 154
agent-based simulation, 161
future integration, 162, 163
MaaS, 154
micro-transit mainstream, 154
multimodal commutes, 160
network flow models, 160
research efforts, 154
ride-matching technologies, 160
simulation-based models, 160
strategy of deployment, 155
car dependence, 156
cost, 157
human element externalities, 157
policies, 155
potential barriers, 155
tech-savviness, 157
trust, 156
value, 157
tactical plans, 158, 159

L
Liability attribution, 57, 58
Local Autonomy Assessment, 78–81
Local Autonomy Index, 77–78

M
Master Plan for Motor Vehicle Policy, 25
Mobility as a Service (MaaS)
  Business Ecosystem theory, 186
  disruptive innovation, 184
  eco-innovation, 186
  ecosystem, 185
  low-or high-tech transport modals, 188
  MaaS 2.0, 186
  overview, 182
  PSS concept, 185, 186
  smart cities, 184
Mobility Orientation Act, 40
Mobility-as-a-Service (MaaS) schemes, 17
Motor third party liability (MPTL) insurance, 61
Motor Vehicle Management Act, 32

N
National Industrial policy, 64

O
Object Event Detection and Response (OEDR), 56
On-demand public transport (DRTs)
  operating costs, 9
  public subsidies, 9

P
PACTE Act, 38, 39
Product-Service System (PSS), 185
Public transport
  in Brazil, 168, 170
Public transport automation
  urban streets and avenues, 5
Public transport operators (PTOs), 8

R
Regular-line transport (RLT), 8
Regulatory Openness for Autonomous Driving Index (ROAD Index), 53, 74, 76
  cities regulatory framework, 75
  Copenhagen, Denmark, 70
  definition, 63
  Geneva, Switzerland, 71
  governance and integration, at local level, 68, 69
  local territories autonomy, 67
  Luxembourg City, Luxembourg, 70
  Lyon, France, 70
  National Industrial policy, 64
  national policy for sustainable development, 66
  scoring, 72, 73
Road Traffic Act, 32
Robomobility, 3, 52, 53
  administrative law, 61
  civil law, 61
  criminal law, 61
  European framework, 59
  international framework, 54
    cybersecurity and personal data protection, 56
    liability attribution, 57, 58
    safety and integration, in road traffic, 55

S
Sustainable mobility system
  transition, 171
    BRT, 173
    electrical/hybrid buses, 173

T
Total Cost of Ownership (TCO), 90, 91
Transport Organization Authorities (TOAs), 195, 198

U
United Nations Economic Commission for Europe (UNECE), 54
United Nations regional commissions administered by the Economic and Social Council (ECOSOC), 54
Urban public transport revolution
  blockchain technologies, 212
  COVID-19 pandemic, 213
  deployment of robomobility, 213
  MaaS framework., 212
  V2X implementation, 212
User-centered mobility, 134
  approaches, 135
  autonomous shuttles, 138
  customer experience and satisfaction *vs.* user experience, 148

User-centered mobility (*cont.*)
design science community, 134
diagnosis
mobility problems, 140–142
research methodology, 139
innovation phases, 142
ambition perimeter, 145
methodology, 143
mobility problems, 144
mobility profiles, 144
mobility solutions, 144
Mooment, 145
value bucket, 145
innovation phasesride sharing button, 145
multidisciplinary issues, 135
personal trip, 134
trial analysis, 136–138
UX design of digital interfaces *vs.* user experience of whole system, 147

V
Validation for System Safety (VSS), 56
Vienna Convention on Road traffic, 54

W
World Forum for Harmonization of Vehicle Regulations, 54