The Future of Transport Services

Transport Division

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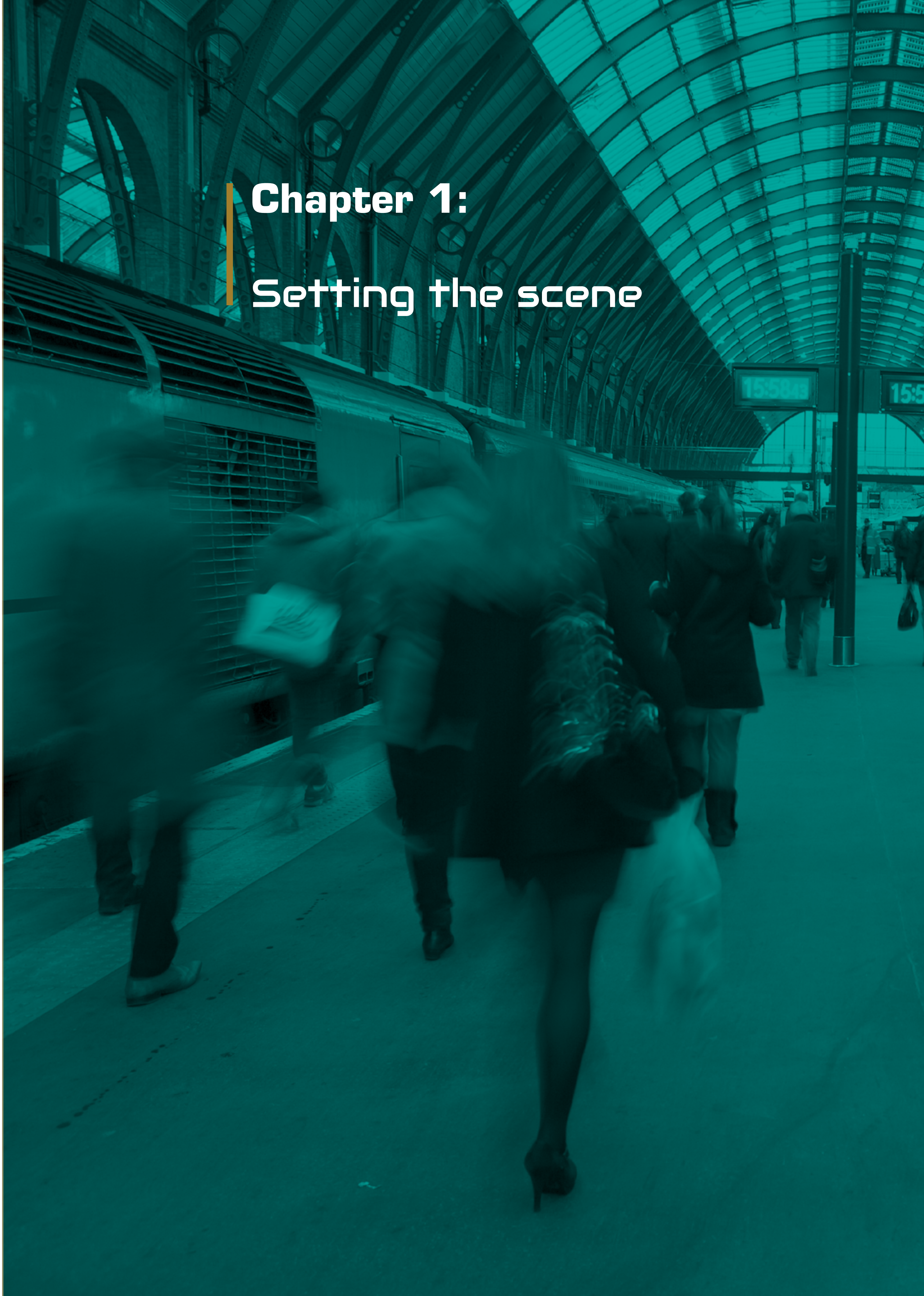
Chapter 1:

Setting the scene



1.1 Background and policy context

The scope of this discussion paper is to describe the main trends disrupting transport services and the policy implications for Latin American and Caribbean (LAC) countries; this includes both those issues already being felt today, as well as those "on the horizon". This paper looks at the two singular global trends that have a direct link to transportation services: disruptive innovation and the sharing economy; followed by a detailed discussion of more specific transportation trends. The core of the discussion would then be on the use of electric vehicles and the varying levels of vehicle automation; and, more importantly, the types of transportation business models which might emerge based on technologies. The implication on transport policy and requirements for government oversight would also be analyzed.

We are now witnessing profound changes, potentially even a paradigm shift or a Mobility Revolution —to use the popular "buzz words"—, in how transport and mobility are both being provided and used, enabled by advances in information and communication technology (ICT), sensor technology, communication technology, and data science; in addition to ubiquitous use of smartphones, mobile internet access, and use of various forms of social media. With a significantly raised profile of transport and mobility on a political, societal, and technological level, they are at the interface of the global megatrends of the sharing economy: disruptive innovation and big data.

Disruptive innovation is a term in the field of business administration which refers to an innovation that creates a new market and value network, and eventually disrupts an existing market and value network, displacing established market-leading firms, products, and alliances. It was defined and first analyzed by Clayton M. Christensen in 1997. Disruptive innovations tend to be produced by outsiders and entrepreneurs, rather than existing market-leading companies. An example of disruptive innovations are ride-hailing and other services commonly referred to as transportation network companies (TNCs) and the rise of platform-based mobility services.

The Oxford Dictionary defines the term sharing economy as "an economic system in which assets or services are shared between private individuals, either free or for a fee, typically by means of the Internet". The key driving forces behind the rise of sharing economy include information technology and social media, social and online commerce, and increasing volatility in the cost of natural resources. The sharing economy relates to shared mobility concepts, including new business models that allow the shared access to, shared use of, and shared ownership of vehicles (for more definitions see section 3.1).

The term big data is commonly defined as high-volume, high-velocity, and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation. Whilst the term is relatively new, the act of gathering and storing large amounts of information for eventual analysis is ages old. The concept gained momentum in the early 2000s, when industry analyst Doug Laney articulated the now-mainstream definition of big data as the three Vs: volume, velocity and variety. Using big data in transportation could increase efficiency and reduce costs to infrastructure and service operators.

While large differences exist globally —based on socioeconomic factors, societal and cultural norms, urban transport infrastructure development, and quality and availability of public transport—, transport and mobility with its long unchanged separation in public and private modes, and legacy services, certainly is in flux. Not a day seems to go by without the news of a new start-up entering or exiting the market, with business models ranging from ride-hailing platforms to dockless bike sharing and electric scooter sharing.

But it is also important to attempt to look beyond the hype often artificially generated by those relying on attracting large sums of money from venture capitalists in order to get start-ups off the ground or to maintain operation and expansion. Shared mobility is still a relatively new field, therefore business models and preferred technologies are still in constant change. According to an analysis described in the Transit Cooperative Research Program (TCRP)'s Research Report 188, current systems and services include the following: bike sharing, car sharing, demand responsive transport systems, fixed-route systems, micro-transit, mobility on demand, para-transit, private shuttles, public transport, ridesharing, carpooling, ride sourcing, ride-splitting, dynamic carpooling, and specified public transportation. The same study generally defines shared mobility as a wide range of transport services having in common that they are shared among users. A study by management consultancy McKinsey on new business models and technologies emerging to solve mobility challenges compiled a comparative characterization of mobility solutions (see table 1).

The type of transport services currently provided through the app-based platforms provided by TNCs, matching passengers with drivers, are operating in the traditional for-hire passenger transport services market. These services include taxis, for-hire cars with drivers and some forms of on-demand micro-transit. They have a long history predating public transport and have been a feature of large and medium-sized cities around the world. Furthermore, they have been an essential component of

Table 1 | Characterization of mobility solutions

	Traditional mobility solutions	New mobility services	
Individual-based mobility	• Private car ownership • Rental cars	• Car sharing: peer-to-peer	• A platform where individuals can rent out private vehicles when they are not in use
		• Car sharing: fleet operator	• On-demand short term car rentals with vehicle owned & managed by a fleet operator
Group-based mobility	• Public transport: group mobility • Public transport: mass transit	• On-demand private shuttle	• App and technology enabled, cheaper than a taxi, more convenient than public transport
		• Private buses	• Use of shared commuter bus fleets available to the public or to employees of companies

Source: (McKinsey, 2015)

Box 1 | Key common predictions for future transport and mobility trends

- **Autonomous**
- **Connected**
- **Electrified**
- **Shared**

well-functioning mobility in metropolitan areas, as they deliver convenient door-to-door trips for those who either punctually or regularly require such services. Though they only account for a small share of overall trips, they are essential for some people, at some times, in some circumstances.

They are a stand-alone part of the urban mobility offer, but can also serve as an important addition to multi-modal public transport provision, walking, cycling, individual cars or car-sharing services. But they are now facing significant disruption due to the arrival of new mobility services based on app-based platforms, these services are known by several names, including ride-sourcing companies, e-hailing, on-demand information technology-based transport aggregators, commercial transport intermediaries, and transportation network companies (TNC). TNC platforms have sometimes been called ridesharing, but the terms ride-sourcing and ride-hailing have been developed to describe the transportation services associated with TNCs. Some early reports used the term ride-sourcing to clarify that drivers do not share a destination with their passengers and that the driver's primary motivation was income. The term ride-sourcing means the outsourcing of rides.

1.2 Overview of key transport trends

Whilst it is not yet possible to determine which new mobility solutions and services would have a lasting and transformative effect and what the time scales for implementation are, let alone doing this for a global regional breakdown, some key trends are nevertheless becoming more and more evident and thus justify looking at more carefully going forward. When reviewing the exponentially increasing output on predicting future transport and mobility trends from international organizations, national governments, academia, the private sector (strategy consulting, for example) and from think tanks, the same four components of a future scenario appear time and again: different combinations of the letter "A", "C", "E", and "S":

- **A = Automation:** for example, the automation of the driving/vehicle control tasks; both for individual vehicles and fleet vehicles, including private cars, buses, taxis, and heavy good vehicles (HGV); either as a road safety relevant add-on in private vehicles, or as a more transformative option of enabling robo-taxis or automated shared mobility services.

- **C = Connectivity:** for example, vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication connectivity, enabling large and real-time data exchange, or a combination of these (V2X); either as a warning system for incidents (being able to look around a curve) or a necessary communication backbone for large automated vehicle fleets.

- **E = Electrification:** for example, move towards the use of electric vehicles both for private cars as well as for fleets, including consideration of charging infrastructure. Arguably, a widespread

move to fully automated vehicles is likely to occur in parallel with electrification for technology reasons (such as use of actuators to control driving functionalities being more appropriate with electronic vehicles —EVs).

- **S = Sharing:** for example, sharing of vehicles as well as sharing of ownership and of access to vehicles, whilst a focus is on cars and mini-buses in this context, sharing of (often electric) bikes and scooters (also now increasingly dock-less) is of importance here too.

In the attempt to formulate the key trends for future transport and mobility, three of the above can form the category "technology trends" (such as automation, connectivity, and electrification); the fourth of the above (shared) can form the category "business model trends", including shared ownership, shared use, mobility platforms; and a third can be defined as "societal trends", relating to car ownership levels, mobility behavior, and privacy attitudes. This shall serve as a basis and analytical framework for the purposes of this discussion paper. See below for some future prediction of service uptake.

1.3 Government roles and responsibilities

The role of the public sector relates mainly to policy definition vis-à-vis formulation of appropriate regulatory frameworks to safeguard key policy objectives in this space, locking in positive impacts, while avoiding negative outcomes. At the same time, a certain level of flexibility is needed, in order to be able to spot unintended negative impacts early and to formulate a revised policy response quickly.

Regulating transport and mobility needs to strike a balance between encouraging entrepreneurship of operators, ensuring the social dimension of public transport, and ensuring service quality and customer satisfaction. In the advent of emerging shared mobility concepts using automated vehicles (AVs), traditional regulatory frameworks, which are already being stretched to accommodate current advances, might reach breaking, requiring different approaches for novel systems.

A key issue is the relationship between new emerging mobility services with legacy systems and operators. Under these circumstances, it has to be recognized that levels of regulation (and indeed active deregulation) and policy support for public transport varies widely around the world. The table below shows an overview of general public transport policy stakeholders and responsibilities according to the International Association of Public Transport (UITP) training material on regulatory principles.

Table 2 | Public transport policy stakeholders and responsibilities

Level	Actors	Role
Strategic (Long term)	National government	• Legal framework • National transport policy • Financial support to local government
	Local government	• Transport policy • Budget • Fare policy • Local regulations
Tactical (Medium term)	Transport authority	• Public transport network • Service levels • Contracting operators • Ticketing system • Information and marketing • Investments in infrastructure
Operational (Short term)	Transport operators	• Transport operation • Investments in rolling stock • Customer service

The relevant general tasks of a transport authority in the context of the regulatory frameworks and wider transport policy considerations for public transport services include the following:

- **Market organization:** elaborate market regulation and procurement strategy and standard contract, and advise on the regulatory framework.

- **Management of budgets and assets:** estimate fare revenues, operating costs, define fares, define ownership of infrastructure, fleet systems.

- **Defining the level of service:** define the route network and transport modes, define operating hours and frequencies per route.

- **Monitoring and payments:** monitoring of operators' performance, determination of service fees, bonuses and penalties.

- **Integrated approach:** ticketing, information (online and offline), marketing and promotion campaigns.

- **Infrastructure:** bus terminals/bus stops, dedicated bus lanes and priority, traffic management, parking management, non-motorised transport.

The technical discourse on vehicle automation and mobility services often appears to assume that there is a "one-size-fits-all" solution. While from a business perspective this would be ideal, in reality, implementation would likely require a much more tailored approach. As a first step for approaching this, it could be useful to define various deployment categories, which have to be addressed before going forward, and where large geographical differences exist. These may include:

- Social, societal, and demographic factors.

- Economic level and income distributions.

- Car ownership levels and car culture.

- Technological differences (for example, access to 5G communication infrastructure).

- Existing layout, size, density of the urban form.

- Characteristics of the built environment.

- Specific requirements for megacities.

- New cities, green-field and brown-field developments.

- Current modal provision and share.

- Legal and regulatory frameworks in place.

- Various other cultural issues.

By recognizing the need for decision-makers to actively manage the transition period of the now emerging new mobility solutions and services, it is necessary to analyze existing regulatory principles, both given their initially intended application, as well as their current use in the context of changing technologies, services, and policy objectives. Under these conditions, we are now witnessing a "stretching" of (greatly unchanged) rules and regulations. This constitutes an imperfect but comparably easy approach, which has both advantages and disadvantages.

While this is still feasible for lower automation levels (assistance), we are likely to encounter the "breaking point" —following this analogy— when nearing full autonomy. This then means that policymakers may either risk regulatory difficulties and lose control over developments or hinder innovation and technology uptake. There is thus a need to develop more flexible regulatory approaches, and in the long term consider a move to more data-driven governance, rather than the use of traditional descriptive approaches, such as a regulations paradigm change in response to a mobility paradigm change.

Regulation in the context of AVs typically centers on the vehicles, where work is ongoing on many levels nationally and internationally. This includes updates to the texts of the agreements under the United Nations Economic Commission for Europe (UNECE) WP.29 regulatios, about the concept of a "driving tests" for AVs, and test tracks simulating various real-life scenarios. In addition, many governments are amending their legal frameworks to allow testing on public roads. A key future challenge would be how to deal with the regulatory aspect of vehicle functionalities changing

through over-the-air software updates. Options include more self-certification elements, as currently used, for example, in the United States.

Regulating the automotive aspect of AVs (for example, through type approval processes) is key, of course, but the likely implementation of this technology as an enabler for different types of shared mobility concepts might require regulation of mobility services to be considered in parallel with more vehicle-centric regulations. There is direct competition with legacy transport services in that case, which are often heavily regulated and protected. Here the disruptive potential is most directly experienced, thus new, more flexible frameworks need to be found.

Characterization of technical capabilities of different levels of vehicle automation and the corresponding driver roles and responsibilities is usually carried out according to the levels provided by the Society of Automotive Engineers (SAE) (see box 2).

While policy responses need to be developed to ensure that the promise of positive effects of the mobility revolution can be achieved, there is also the potential of undesired effects as a result, which need to be addressed too. This may include avoiding a modal shift away from green modes (walking, cycling, and mass public transport), ensuring appropriate minimum mobility levels for all citizens, and guaranteeing high levels of road safety and personal security.

Box 2 | SAE levels of vehicle automation

SAE J3016 Levels of driving automation

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
ADAPTIVE CRUISE CONTROL		✓	✓	✓	✓	✓
PARALLEL HELPER-L1		✓				
ACTIVE LANE CENTERING		✓	✓	✓	✓	✓
PARKING HELPER-L2			✓	✓	✓	✓
HIGHWAY PILOT-L2			✓	✓	✓	✓
TRAFFIC JAM PILOT				✓	✓	✓
AUTOMATED DRIVING SYSTEM-L3				✓		
AUTOMATED DRIVING SYSTEM-L4					✓	
PARKING VALET					✓	✓
AUTOMATED DRIVING SYSTEM-L5						✓
		ASISTED		AUTOMATED		

LEVEL 0: NO DRIVING AUTOMATION: YOU DRIVE; THE VEHICLE CAN PROVIDE DRIVING ASSISTE FEATURES.
LEVEL 1: DRIVING AUTOMATION ASISTANCE: EITHER STEERING OR BRAKING ASSIST BUT NOT AT THE SAME TIME.
LEVEL 2: PARTIAL DRIVING AUTOMATION: STEERING AND PARKING ASSIST TOGETHER AS SUPPORT FETURE ONLY; HUMAN DRIVER MUST SUPERVISE.
LEVEL 3: CONDITIONAL DRIVING AUTOMATION: AUTOMATION OF FULL DRIVING TASK WITH HUMAN FALLBACK; DRIVER MUST RESPOND PROMPTLY WHEN ALERTED.
LEVEL 4: CONDITIONAL DRIVING AUTOMATION: FULL AUTOMATION BUT ONLY IN PREDETERMINED CONDITIONS; HUMAN MUST DRIVE WHEN SYSTEM NOT ENGAGED.
LEVEL 5: FULL DRIVING AUTOMATION: YOU NEVER HAVE TO DRIVE ENYWHERE UNLESS YOU WANT TO.

There is thus a need to monitor, for example, overall person-miles-travelled. AVs need to be seen as part of the overall multi-modal system. It should also be considered the livelihood, training and pension of sector employees. Access to data sets for analytics and enforcement purposes is necessary, and an element of pricing might be essential to provide "nudges" for transport users to make the right choices.

The expert discourse on the regulatory response is often split between those advocating "heavy" regulatory oversight in order to ensure maximum safety levels, and those who see this approach as an unnecessary burden on innovation, slowing down the implementation of valuable systems and technologies. A way forward here would be the use of regulatory "sandboxes", where market access is made easy, but only temporarily, as to monitor effects.

Other essential policy areas to address are road safety, labor market impacts of automated vehicles, and the question as to how to regulate TNCs in such a way that they can co-exist in a less disruptive way together with legacy transport carriers, particularly the high regulated tax industry. Some road safety principles may include:

- Testing: from simulation to private track, public roads with a safety driver, and then public roads.
- SAE Levels vs policy vs customers expectation (need to find more targeted communication).
- Avoidance of any brand-specific performance standards.
- OEMs, to develop specific cybersecurity policy.
- Broadening regulatory framework (for example, infotainment).
- Consideration of future scenarios and moving towards new mobility services (fleets) for policy advise.

In addition, labor market impacts are likely to arise as a result of advanced automation technology, particularly in the road freight sector. Here there could be substantial job losses amongst drivers, within a decade, and job losses in the order of 1 million people in of the European Union (EU) and North America are possible, according to a study on automated road freight transport (ITF, 2017b). Even though the focus is on truck automation, some analogue lessons learned can also be deduced for the taxi industry and public transportation.

Moreover, unlike previous circumstances, drivers displaced by automation may struggle to find alternative employment. However, there is also a potential for improved employment opportunities, with an operator still in the cab and more back-office service sector work. Furthermore, estimations of job losses differ widely between different regions, with some quoting substantial shortages of drivers currently to be replaced by automation. Measures for addressing labor market effects may include:

- Establishing a temporary transition advisory board to consult governments on these strategies.
- Permit system to influence the speed of technology introduction of and the associated job losses.
- Economy-wide support of underemployed drivers, such as universal income policies.
- Industry-specific support consistent with good practice for general unemployment support.
- System to be funded by the primary beneficiaries of the advanced technologies.

More flexible regulatory principles for TNCs should be founded on the following guiding principles:

- Regulation should be limited to correcting market failures based on sound economic principles.
- Regulation should rely on the most efficient tools (e.g. data-driven regulatory approaches).
- Regulation should be technology neutral and not discriminate between operators in a market.

- The impact of regulation and its relevance should be monitored and re-assessed.

- Regulation should be adaptable, focused, clear, and easy to apply.

- There should be an adequate division of regulatory responsibility.

- Regulation should be inclusive of all social groups.

1.4 Objectives and analysis approach

This discussion paper on the future of transportation in the LAC region covers the key transport and mobility future trends introduced above in general terms, including risks and opportunities; the role of the public sector in shaping these trends, and the specific situation LAC countries.

The figure below shows the analysis methodology used as a background for this discussion paper; which identifies the 3 key trends to consider, looking at specific examples for these trends in the next step, and then going through a formal process of analyzing each of the trends. This establishes a basis for formulating a number of propositions as to how these trends could materialize in the region; together with the necessary policy responses required.The key trends discussed are:

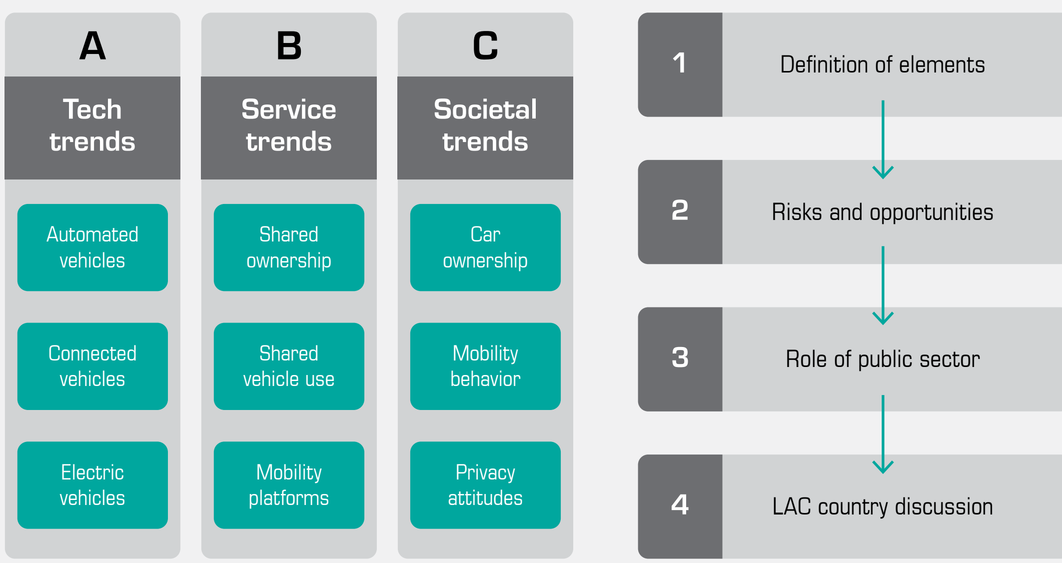
A. **Technology trends:**

- Automation.
- Connectivity.
- Electrification.

B. **Service trends:**

- Shared ownership.
- Shared use.
- Mobility platforms.

Figure 1 | Key trends analyses and methodology used



C. **Societal trends:**

- Car ownership.
- Mobility behavior.
- Privacy attitude.

For each trend the following methodology applies:

1. Definition of elements.
2. Risks and opportunities.
3. Role of the public sector.
4. Latin America and the Caribbean (LAC) country discussion.

To the backdrop of these trends, their implications, and the necessary policy responses, some very specific counteracting factors identified for LAC countries would be discussed, including:

- Pushback from car manufacturers due to additional costs from automation and safety features.
- Pushback from taxi/bus drivers due to concerns of potential labor market effects of automation.
- Societal factors such a car seen as an aspirational status symbol counteracting service adoption.

Chapter 2:

Technology trends

2.1 Definition of elements

Implementation of different levels of vehicle automation can already be found and it is likely to continue. These vary along the 5 SAE automation levels, ranging from various degrees of driver assistance to full automation, in geo-fenced areas and ultimately anywhere. Moreover, it can take place in privately owned vehicles or in emerging fleet-based shared mobility services.

Connectivity and communication between vehicles, either as a separate feature or as a key enabler for vehicle automation and various mobility services, is another likely critical feature of future mobility. And it includes V2V, V2I, or a combination of the two (V2X). Key questions here are technology options (for example, 5G cellular communication vs G5/ DSRC short-range communication) or funding (public or private sector). In this context, it should be observed the European Commission (EC) backed initiative on Cooperative Intelligent Transport Systems (C-ITS) and the associated legal documents.

Digital technologies have developed rapidly over the past decades and they are increasingly being introduced in transport. While Intelligent Transport Systems (ITS) focus on digital technologies providing intelligence placed at the roadside or in vehicles, C-ITS focuses on the communication between those systems. Vehicles and infrastructure equipped with C-ITS can communicate a warning to each other, after which the drivers are informed about the upcoming traffic situation in time for them to take the necessary actions in order to avoid potential harm.

The European Commission outlined its plan for the coordinated deployment of C-ITS in Europe in its communication "An European strategy on Cooperative Intelligent Transport Systems". Incident warning functionalities are a clear key application of vehicle connectivity, and they would enable vehicles located downstream, which have detected or encountered an incident, to relay this information to vehicles up-stream, out-of-sight, effectively allowing them to "look around the curve".

Another application of vehicle connectivity would be for the scheduling of fleet-based systems, which after reaching a critical mass would very likely require such communication bandwidth for the scheduling of vehicles. An analogue case would be a very widespread uptake of high levels of automation in private vehicles, where connectivity might be necessary for safe operation. Thinking this further, there could even be a move away from signal control traffic management to "swarm-like" approaches (with a central control system giving/restricting priority on a single vehicle basis). To accomplish this, again, connectivity and high bandwidth would be essential.

Further likely, transport related trends include a move towards the utilization of clean vehicle technology and fuels, with a wide-spread uptake of electric vehicles and use of alternative fuels. Uptake would be linked to potential government subsidies for such vehicles, the success of private sector

products and services, and the provision of the necessary charging infrastructure.

With the use of electric vehicles, both for privately owned cars or for fleet-based mobility services, vehicle charging infrastructure requires closer scrutiny. Whilst battery technology still limits the range of electric engines, quick charging (or battery swapping, amongst other alternative ideas regarding this issue) is a crucial enabler. Here, some questions arise: who would finance this (public or private sector) and what granularity of charging points throughout the network is required? We are now seeing multiple vehicle manufacturers attempting to build up their own infrastructure, in addition to varying levels of public sector efforts in this space. Other issues to consider in this matter include the regulatory response to safe disposal and recycling of EV batteries, plus other existing technological challenges, such as battery technology, that still generates higher costs, thus affecting technology uptake.

One of the first real world applications of Automated Vehicles (AVs) was the ParkShuttle in the Rivium Business Park near Rotterdam in the Netherlands. Open to the public in 1999, it consisted of a shared, automated shuttle carrying passengers on a loop with a number of stops connecting offices to nearby public transport interchanges. A similar system connecting the long-stay car park with the main terminal building of Schiphol airport was set up as a multi-year demonstration, which ceased operation after the end of the trial period. Both systems, although segregated from other traffic on some parts of the route, were able to operate safely with manually driven vehicles and pedestrians in controlled but mixed environments. The Rivium system has been extended, with second generation vehicles, and is still operational today. Similar kinds of shuttles are now being tested around the world (in cities like Paris, Singapore, and within the United States) with about 10 different suppliers present in the market.

Most of these systems share similar parameters, including:

- **Low speeds:** operational speeds are often below 15 km/h, but higher speeds are possible depending on segregation, as maximum levels of jerk for emergency braking need to be adhered to for safety reasons.

- **Simple and controlled environments:** to minimize interaction with other traffic, vehicles operate, for example, in pedestrian zones, university campuses, etc.

- **Significant infrastructure:** there are varying levels of separation from other traffic.

- **Supervised operations:** whilst it is not necessary to have operations' staff inside the vehicle, a staffed remote operations center is required.

In a transition period —and while full automation is not yet fully proven and costs are high—, introducing SAE level 1-3 automation (such as still with a driver present) for public transport vehicles could be an interim solution enabling enhanced performance; for example, precision-docking at stations, operation at minimum headways, or allowing narrower lanes, etc. at comparatively lower costs. See below for the set of vehicle and service categories developed as part of the EU-funded CityMobil project (R&D effort investigating the urban use of low-speed light-weight shuttles) that describe different vehicle and service concepts:

- **Cybercars:** fully automated road vehicles for individual or collective transportation of people and goods, and for specific areas with little or no interaction with other vehicles.

- **Personal rapid transit (PRT):** small fully automatic vehicles operating on guideways, segregated from pedestrians and other traffic.

- **Advanced city vehicles (ACV):** integrating zero or ultra-low pollution propulsion and driver assistance systems, allowing integration into car-sharing services.

- **High-tech buses:** buses on rubber wheels, operating like a tram on lanes with light infrastructure using electronic guidance either fully automated or assistance functionalities.

- **Dual-mode vehicles (DMV):** using conventional vehicles, supporting both fully automat-

ed and manual driving. They represent a potential migration path from traditional cars to AVs.

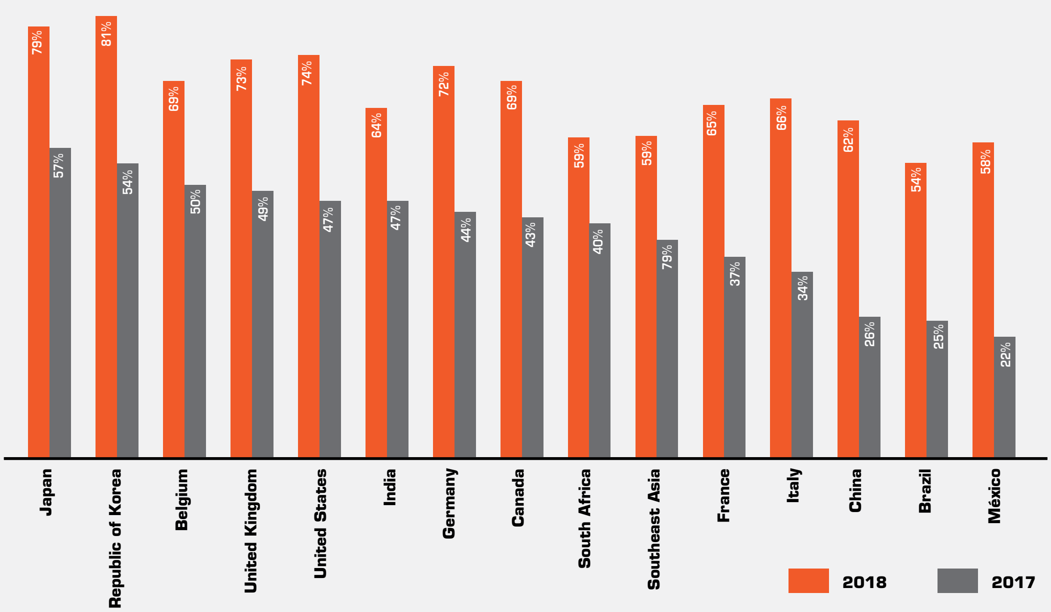
Until true SAE level 5 vehicles are on the market, capable of performing all driving tasks (everything) under all conditions in all settings (everywhere), vehicle manufacturers and fleet operators would have to put certain operational design domain (ODD) restrictions in place to mitigate system and/or vehicle limitations. These ODD constraints include geography, road type, speed, and weather conditions; what's more, system capability and maturity would also require a certain dependency on supporting infrastructure for safe operation.

Restrictions would have to be formulated and enforced by policymakers and regulators, and conflict may arise between realistically achievable ODDs and actual operational or commercial requirements. This is also dependent on timescales, with the government requiring time for developing type-approval regulations and managing new transport services that raise issues similar to TNCs, such as Uber or Lyft.

The public perception of safety plays a key role in this context, conceivably causing a situation where more restrictive than necessary (as suggested by industry and research) constraints on system operation are put in place, possibly creating excessive burdens on vehicle manufacturers and system operators. There is evidence from some automated metros in cities around the world where either a "driver" is still present despite automated operations or a decision to move towards automated operations was reversed due to concern over public perception of safety. The box below shows a recent comparison on survey results into acceptance of AVs. Whilst the level of acceptance is improving, in many markets the majority of people is still not convinced of the safety of AVs.

In the case of shared mobility systems, there would then be concern over the economic viability of a system with a large number of small automated shuttles retaining (for a certain period of time) a manual operator, particularly as savings in personnel costs would be a key motivator for introducing such a scheme in the first place. The dominant

Box 3 | Changes in consumer acceptance of automated vehicles over time (Deloitte Insights)[1]



1. Giffi, Craig A., Vitale, Joe, Schiller, Thomas, Robinson, Ryan. (2018). "A reality check on advanced vehicle technologies", Deloitte Insights. Retrieved from: https://www2.deloitte.com/insights/us/en/industry/automotive/advanced-vehicle-technologies-autonomous-electric-vehicles.html

challenge for the developers of the technology would then be to demonstrate convincingly that their technology has reached a level of maturity that it is capable of operating safely in a shared (unprotected) ODD without human operator supervision. This is a challenge that has yet to be met by any of the technology developers. In addition to ODD considerations, specific requirements for accompanying infrastructure may occur:

- **Charging infrastructure:** if electric vehicles are used, a likely option for a number of reasons, then designing and providing the necessary charging infrastructure (offline, or online, at stops or junctions), scheduling of charging of vehicles and routing to charging stations need to be considered as part of the overall service planning.

- **Communication infrastructure:** vehicle and system operation options would depend on provision and level of connectedness using wireless technology. This is particularly important with the emergence of both smart infrastructure with embedded sensors and the Internet of Things (IoT). With the increasing importance of digital infrastructure, it emerges the need to ensure the robustness of system (data protection and privacy) and data coverage. A central control or supervisory scheme with reliable communication systems would be needed for public transport fleets.

- **Other physical infrastructure:** in the transition period, but possibly beyond, physical infrastructure might still be required. This includes varying levels of segregation between automated vehicles and other traffic. Therefore, one might see separate lanes, different types of barriers to limit access to parts of the network and special provisions for junctions. Potential negative effects on urban design, including visual intrusion and the risk of community severance, need to be carefully considered.

The underlying operating principles for such a system might be based on both size and density of urban areas; with the assumption that cities, rather than more rural areas, would be the appropriate geographical setting for shared services. Long-distance services that connect urban centers may be feasible, but private companies would focus on highly dense urban areas, as the operation of vehicle fleets would depend on investment into mapping. The vehicles to be used are likely to have the following common characteristics:

- **Electric propulsion:** the control mechanism and actuators involved in automated operation make electric propulsion the probable option for AVs. The environmental performance of electric vehicles, with lower noise levels and no emissions at the point of operation, would further suggest their use. Also, mandating EVs for specific vehicle fleets, for example, public transport, is a viable policy option to influence the transition period positively.

- **Light-weight vehicles:** traditionally, the vehicles used in existing applications are relatively flexible and light-weight vehicles from non-conventional vehicle manufacturers. An immediate concern for a more widespread deployment of these types of vehicles would then be their safety performance. Addressing this issue might involve the development of specific standards to ensure the necessary road safety levels, particularly in mixed traffic with heavier and larger manually operated vehicles.

- **Tailor-made vehicles:** whilst potentially being based on a generic foundation or chassis, the vehicles are likely to be required to be tailored to local characteristics in order to ensure the success of the system. These include cultural and geographical characteristics, business models used, customers targeted, as well as the location of the systems. The new and emerging business models in the AV space are likely to produce tailor-made vehicles serving a multitude of purposes, which may include convenience stores, meeting rooms, hotel rooms, etc. on wheels. It is essential to take specific care needs to make the vehicles, and the system as a whole, accessible to disabled and elderly users.

Besides, the design of all internal and external user interfaces should be paid special attention, in a similar way to how TNCs and ride-hailing platforms currently operate:

- **Booking a service:** a smartphone, app-based platform needs to be in place, which can be understood and used by all passengers independent of individual characteristics, otherwise, it might prevent them from accessing mobility services. These may include social and economic background, banking penetration or financial inclusion, age, information technology (IT) literacy, or physical impairments. Alternative means of access would also be needed for those without access to smartphones.

- **Accessing and using the vehicle:** a system needs to be in place for users to be guided through the process, including finding the access point, recognizing the booked vehicle, gaining access, and —once on-board— being reassured of the prebooked destination, and being advised on the route and any intermediate stops. Also, all back-office function for billing and multimodal ticketing need to be designed and implemented.

- **Interactions in mixed operation:** AVs must be able to communicate with other vehicles and road-users, including pedestrians and cyclists, in mixed-use environments. Use cases for this can include negotiating narrow, congested areas; giving way or asking others to give way, and preparation for turning, among others. Some communication channels could be displays or lights on the outside of the vehicle and/or with targeted messages on users' smartphones.

2.2 Risks and opportunities

A possible benefit of vehicle automation is improved road safety performance. By removing the human element from the operation of road vehicles, a certain number of road traffic crashes are likely to be avoided; predictions for the scale of improvements vary widely and, importantly, these statements remain untested. The performance of varying levels of automation have been modelled and tested in private sites, and have been in actual use; most notably here are Tesla, in the context of private cars, and Waymo (formerly Google) and to some degree Uber for mobility services. But the effects of a mass introduction are still uncertain at this point. And whilst road safety improvements are very likely, they need to be seen in the context of the Vision Zero approach, in addition to the ethical questions of a potentially fatal accident caused not by a human but by an algorithm.

Furthermore, some new accident scenarios can be envisioned, particularly in the —likely prolonged— transition period where the road space would be shared by vehicles of varying levels of automation and fully human-operated vehicles. Another issue in this subject is that initially human drivers and other road users, including pedestrians and cyclists, would have no experience with the ways in which the "behavior" of automated vehicles would differ from human operated ones, which has high possibilities of being the case; there might even be differences between technologies and brands.

Some minor positive environmental impacts can be expected from the introduction of automated vehicles, based on programmed-in optimal driving styles (such as eco-driving) and aerodynamic effects from minimal inter-vehicle headways at high speeds (in the case of superhighways, rather than in slow urban traffic). These effects are likely to be on a scale, that as part of a wider decarbonization of transport effort can play a role, but not be a justification on its own for government efforts for a roll out of automated vehicles, based on, for example, contributions to reaching the United Nations' Sustainable Development Goals (SDG).

Much larger pollution improvements —at least at the point of operation— can be expected from a mass introduction of electric vehicles, contributing to cleaner and quieter urban environments. Road safety with nearly silent vehicles is another issue to be considered, along with the question of how the energy is generated for it, range issues, and the need for a comprehensive charging infrastructure.

In an analogy to the environmental performance of automated vehicles, some minor capacity gains on network or link level are also to be expected. This is based on, again, smaller headways, potentially the use of narrower lanes, and optimal routing and traffic management. In this context, there might be a concern about how capacity improvements and decreases in congestion level might lead to

induced traffic, the same effects new or upgraded infrastructure can have, therefore rendering positive ineffective by the increase in demand that they generate.

But much larger effects can be expected from the wide-spread introduction of mobility services, assuming that these services would radically change mobility behavior and —most importantly— increase vehicle occupancy rates from current average values of 1.2 in commuter traffic at peak hours to much higher levels (for example, 6-8 in a mini-bus); this could potentially free up large spaces in urban areas with much less need for parking spaces.

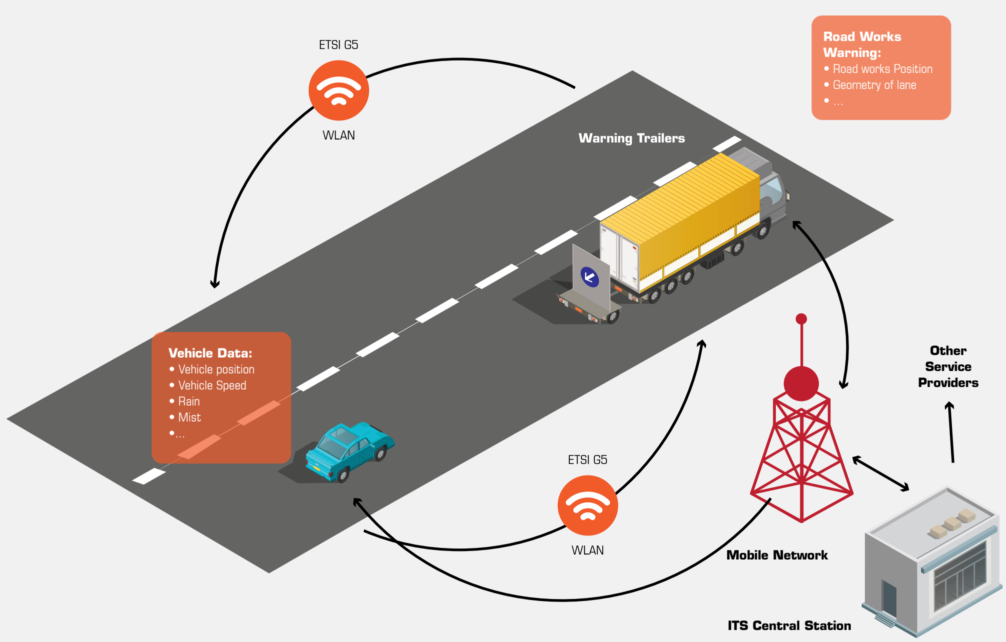
On the other hand, negative effects are also possible without the necessary accompanying policy measures, including increased vehicle-miles travelled (VMT), increased urban sprawl, among others, but as these are based on the individual business model enabled by new technologies, the more detailed discussion of these risks is in the following chapter on service trends.

2.3 Role of the public sector

Decision makers need to actively manage the transition period to new mobility services, locking-in potential benefits while avoiding potential negative effects. Policies here may include financial incentives for cleaner and safer cars, encouraging uptake of electric (or potentially other clean fuels) vehicles and cars with enhanced safety feature, including lower automation levels providing advanced driver assistance functionalities.

Likewise, there should be an introduction of relevant industry standards for vehicle safety, guaranteeing minimum safety levels in the fleet by mandatory onboard technology for all newly purchased vehicles. Here, specific trade policies may also be considered, banning or regulating the quantity on of non-AVs. These safety and assistance systems could also include lower levels of vehicle automation. These efforts could also potentially follow a similar path as the efforts of the New Car Assessment Programme (NCAP).

Box 4 | The EU Cooperative Intelligent Transport Systems (C-ITS) Initiative[2]



2. C-ITS Platform Phase II chaired by the European Commission. Retrieved from: https://www.polisnetwork.eu/uploads/Modules/PublicDocuments/phase-ii---c-its-platform---draft-final-report---september-2017_v1.0.pdf

Another question in this context would be the issue of funding for V2X communication systems and infrastructure. Some experts argue that high levels of communications between vehicles and infrastructure are either not necessary at all as an enable for high levels of vehicle automation or would only be required at a much later stage when these vehicles reach a critical mass (which might be decades away at this point).

In terms of technology options DSRC/ G5 (see box 4 on the EU C-ITS Initiative) is a lower tech option available now, but which would require funding for road-side infrastructure such as beacons; 5G, on the other hand, would require costly upgrades to the communication infrastructure from mobile phone operators. But with the question of emerging technologies in developing markets, there is always the possibility of "leap-frogging" generations of tech development straight to the latest innovation. In this case, governments would then need to provide the right economic environment in terms of employment and regulations. In-vehicle safety features based on connectivity are likely to be introduced as a pricey add-on service by vehicle manufacturers in the premium segment, decision-makers need to find a position vis-à-vis the public good of road safety improvements. See table 3 for a more detailed comparison.

A similar question arises over the funding for charging infrastructure, which is a critical enabler of a wider uptake of electric vehicle technology. Many vehicle manufacturers, with Tesla certainly currently leading the way here, are investing heavily (or have made public statements committing to this) into their proprietary charging infrastructure. In parallel governments are building up open systems. Decision-makers may want to use their convening power to ef-

Table 3 | Comparison of ITS 5G (DSRC) and 5G Mobile Telephony

	ITS G5 (DSRC)	5G Mobile Telephony
Standardisation	IEEE 802.11 P	3GPP
Availability	Now	Under standardization
Spectrum	5.9 GHz (Europe, United States), 760MHz (Japan), unlicensed spectrum	400 MHz to 100 GHz, licensed and unlicensed spectrum
Latency	Few meters (depends on the number of vehicles on the road)	1 meter
Range	Short: few 100 meters	Long: depends on the frequency
Spectrum efficiency	Low	High
Data rates	3, 4.5, 6, 9, 12, 18, 24, 27 Mbps	High: up to 10 Gbps
Scalability	Medium	High
Network infrastructure	No, direct mode	Both, direct and network mode
Reliability	Not guaranteed	Guaranteed
Security	Encryption, authentication, but no end to end security monitoring/ supervision	Security by design. End-to-end authentication and encryption, access control, supervision, threat management, etc.
Application supported	V2V, V2I	V2X, IoT, infotainment, traffic management, eCall, location services, software upgrades, etc.

fect some standardization or at least a certain level of coordination between these systems and stakeholders.

Another issue that requires government response is addressing a potential decrease of fuel tax income from a mass uptake of clean electric vehicles. Whilst this trend is obviously not to be penalized, it would leave a certain gap in already low public finances and budgets, which are vital for infrastructure maintenance and public transport services. While putting additional tax burdens elsewhere would be politically unpopular, a larger involvement of the private sector, particularly the tech sector, might be a way forward; efficient government oversight of such a move should be essential.

Though vehicle automation might be used for both private vehicles and mobility services, and emerging mobility platforms might cause a modal shift towards single occupancy ride-hailing or to improved public transport services, the public sector needs to provide (financial or other) nudges for a modal shift towards green and sustainable modes and to higher average vehicle occupancy rates.

Since 2011, some jurisdictions have been updating their motor vehicle regulatory frameworks to deal with AVs. Several US states, France and Germany have all enacted legislation specific to AVs. At the international level, amendments have been made to the Convention on Road Traffic, with additional ones currently under discussion. While there are differences in regulatory frameworks, many of those enacted to date have similar elements, including:

- Definition of what constitutes an AV and automated driving.
- Requirement for AVs to abide by all existing road rules at all times.
- Developer responsibility for what occurs while the vehicle is in automated mode.
- Express legalization of testing AVs on public roads, subject to conditions, such as:
    - Obtaining a permit to test an AV on public roads,requirement for a human driver to be present to take over manual operation at any time,
    - Minimum insurance requirements,
    - Obtaining further approval before commercial deployment.

The cautious approach many regulators have taken to date is prudent, given the current uncertainty. It provides a space to test AV technology and gather real-world data and evidence. Regulators would be able to use this data and evidence for future policymaking. However, there are also limits to this model. As the technology closes in deployment, issues left unanswered by a cautious approach would need to be dealt with.

Perhaps the most important issue that must be addressed relates to how safe an AV must be before regulators allow it to be commercially deployed. Many jurisdictions' AV regulatory frameworks are unprepared to manage this subject. At present, Florida is the only jurisdiction that has AV legislation which consents commercial deployment without a specific permit. All other jurisdictions with AV-specific legislation either limit AVs to testing or require a specific permit for deployment. However, many have not yet developed the requirements for that permit.

In regimes designed for human-driven vehicles, mechanisms that allow exemptions from motor vehicle standards may be called upon to provide a path to AV deployment. For example, the National Highway Traffic Safety Administration (NHTSA) can exempt a limited number of vehicles from US Federal Motor Vehicle Safety Standards, provided a vehicle is safer overall than a vehicle which complies with the standards. Arguably, there are advantages to using this standard for AVs. AV developers would have a target for the level of safety they need to meet, providing greater clarity than they currently have. Also, the overall nature of such a standard might be flexible, allowing AV deployment using a broad range of approaches, so long as they improve road safety.

While the flexibility in NHTSA's exemption processes and California's draft legislation has ad-

vantages, it can also create uncertainty. By having an overall standard or delegating the safety case, these regulatory approaches effectively leave the safety decision at the discretion of the relevant official, and their subjective judgment. In turn, there is a continued uncertainty around how safe would AVs need to be before they are allowed to be commercially deployed. Determining how safe an AV must be to obtain approval for deployment is challenged by both public perception and technical issues.

2.4 LAC country discussion

Against the backdrop of the trends, risks and opportunities, and government roles described, this discussion includes a suggestion of specific policy recommendation tailored to the requirements of LAC countries, in terms of governance and industrial issues. Key local developments in the context of technology trends are less but rising vehicle ownership rates, a generally older fleet with lower levels of technology maturity, and poor road safety performance (see box 5). Furthermore, there is already early resistance from vehicle manufacturers to deploy costly onboard technology and thus increasing retail prices, which would intensify before more advanced driver assistance functionalities and even automation.

In this context, a higher importance should be placed on advanced driver assistance systems, which are ready to be deployed right now and at a comparably low cost, giving a boost to the regions road safety levels. Government policy should focus more on uptake of these systems, rather than on the implementation of fully automated vehicles, which might be less suitable at this stage. Thus, a more nuanced and realistic view on automated vehicles, and to some degree also electric vehicles, would be necessary in order to deploy existing and emerging technologies in the most efficient way.

Box 5 | Selected transport statistics for the LAC region[3]

Figure 1. Registered motor vehicles per 1,000 population in the Region of the Americas, by country, 2010

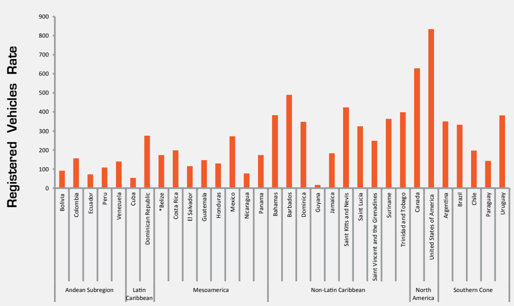


Figure 3. Shares of registered vehicles compared with shares of road traffic deaths in the Region of the Americas, by subregion, 2010

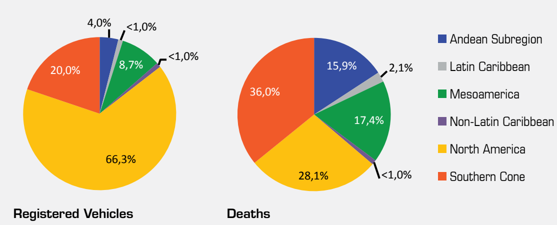


Figure 2. Types of registered vehicles in the Region of the Americas, by subregion, 2010

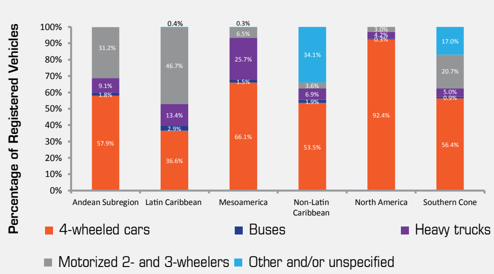
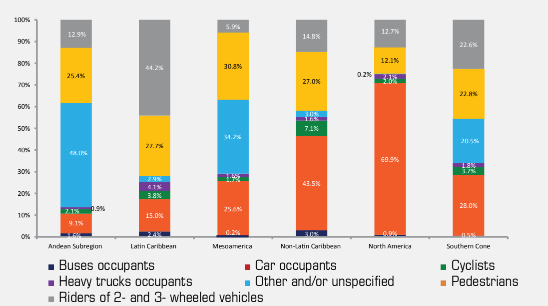


Figure 4. Proportion of reported road traffic deaths in the Region of the Americas, by type of road user and subregion, 2010



3. Road Safety Facts in the Region of the Americas, 2013. Washington, DC: PAHO. Retrieved from: https://www.paho.org/hq/dmdocuments/2013/paho-roadsafe-facts-2013.pdf,

Chapter 3:

Service trends

3.1 Definition of elements

Besides the technology-related trends, there are also various new emerging business models enabling innovative mobility service. This holds the promise for substantial benefits for society as a whole as well as on the city level, and it is based on the concept of shared mobility, which relates to both shared access to vehicles, as well as shared use of vehicles, such as a move away from vehicle ownership to vehicle “usership”. These systems include, among others:

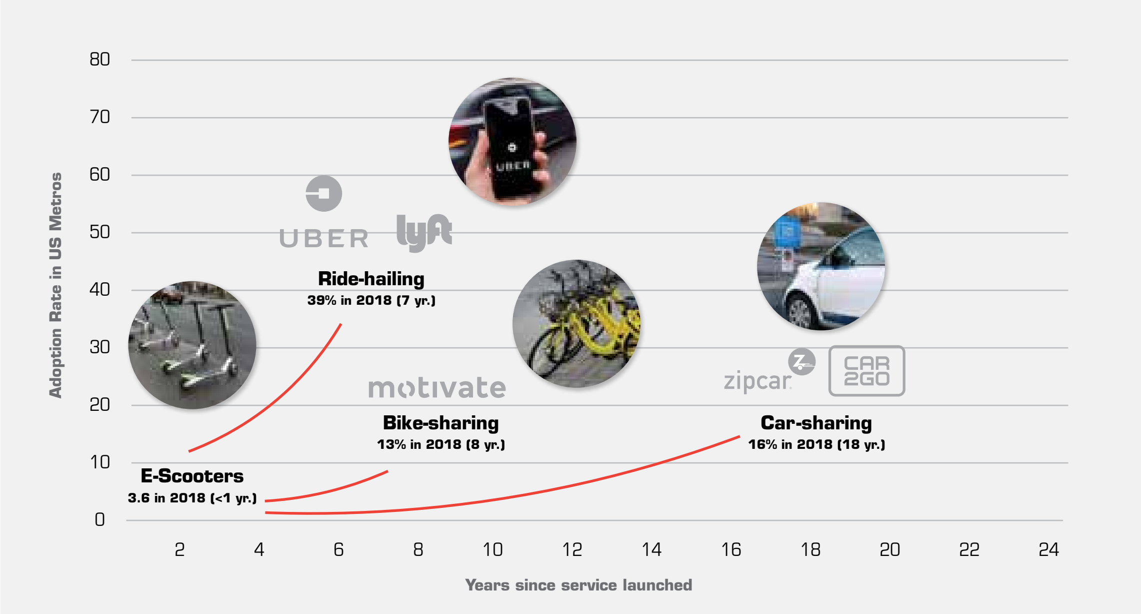
- App-based ride-hailing providers.
- Car-sharing and car-pooling.
- Integrated mobility service platforms.
- The concept of Mobility-as-a-Service (MaaS).
- New modes and approaches (electric scooters and the dock-less model).
- Low-speed first-/ last-mile shuttles.

In recent times, with new iterations of mobility services and business models, the adoption rates can be seen to be accelerating —as illustrated in the box below— showing years since service launched in relation to adoption rates in metropolitan areas in the United States. The cardinal concept behind Mobility as a Service (MaaS) is to put the user at the core of transport services, offering tailor-made mobility solutions based on individual needs. MaaS is the integration of various forms of transport modes into a single mobility service accessible on demand. It combines all possible transport modes, enabling users to access services through a single account with a monthly fee.

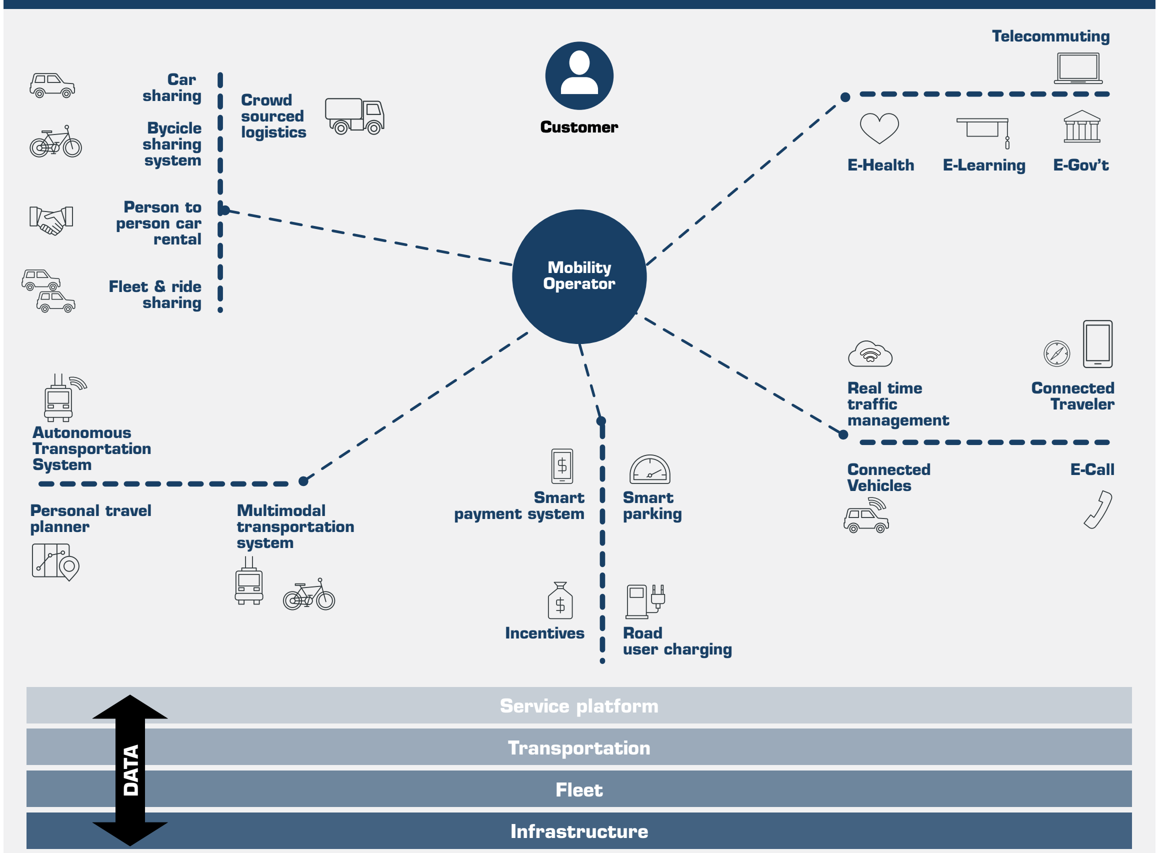
Within the MaaS scheme, users would buy a mobility package according to their profiles and preferences (for example, business mobility package, family package, etc.) and pay a fee accordingly. The package would include access to a number of trips using different transport modes (local public transport, a number of taxi rides, use of a shared car up to a certain amount of kilometers, and others). A single app would allow users to see schedules, search for multimodal travel solutions, book and pay. Box 7 shows an illustration of the Mobility-as-a-Service (MaaS) concept.

For wider mobility services enabled by vehicle automation, it needs to be explored how specific service concepts can be matched to specific operational environments, on a detailed local level as well as across continents and cultures.

Box 6 | Comparison of different mobility service adoption rates



Box 7 | Illustration of the Mobility-as-a-Service (MaaS) concept[4]



4. Retrieved from: https://www.slideshare.net/Mindtrek/sampo-hietanen-discover-the-future-of-mobility-mindtrek-2016

The following definitions of shared mobility components have been made recently:

- **Bike-sharing:** on-demand access to bicycles at a variety of pick-up/drop-off locations for one-way or roundtrip.
- **Ride-sharing:** formal/informal sharing of rides between driver and passenger with similar origin-destination pairings.
- **Car-sharing:** offers members access to vehicles by joining an organization that provides and maintains a fleet of cars.
- **Ride-sourcing** (also often referred to as ride-hailing or e-hailing): on-demand transport service prearranged for compensation, driver and passenger connect via apps.
- **Micro-transit:** transit service that uses multipassenger/pooled shuttle for on-demand or fixed-schedule services.
- **Scooter-sharing:** access to scooters by joining an organization that maintains a fleet of scooters at various locations.
- **Shared motorcycle:** common in developing countries, similar in concept to ride-sourcing, but using motorcycles instead of passenger cars (for example, Uber Moto).

The following industry sector involvements and cooperation projects for testing and demonstrating AV technology in this space are first examples to emerge:

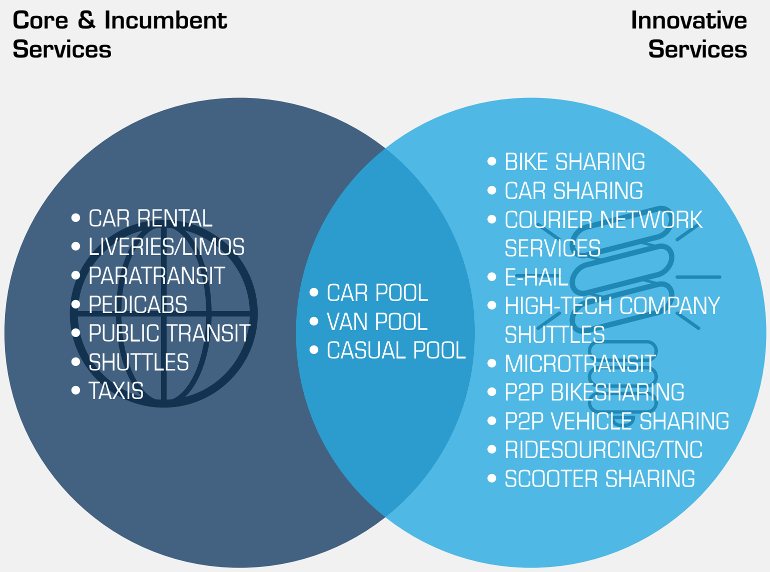
- **Google/Waymo:** full automation in specific geo-fenced areas, using very high definition inch-precision maps of the area the vehicles are expected to use, in addition to on board systems, some computation is performed on remote computer farms.
- **EasyMile:** a low-speed urban shared-mobility shuttle currently being demonstrated in small highly controlled environments with little interaction with other traffic. Demonstrations are being carried out in Paris, and in sites in the Netherlands and North America; although in most cases a safety operator is required inside the vehicle for safety regulatory reasons.
- **nuTonomy:** recently launched its highly automated taxi service as a pilot project in Singapore (still supervised by safety drivers), their vehicles use formal logic to decide their paths in terms of motion, maneuverability, and speed.
- **Uber and Volvo:** Uber started testing the concept of driverless (although in the trial period a driver was still inside the vehicle at all times, to take over in case of unforeseen circumstances) shared mobility service provision in the city of Pittsburgh.
- **Uber and Daimler:** recently announced a strategic partnership through which Daimler would provide tailor-made vehicles to Uber to be eventually used as a highly automated ride-sharing (such as driverless) system.
- **Ford and Cruise Automation:** recently announced plans to offer highly a fully automated (level 4) high-density, high-volume ride-hailing application in geo-fenced parts of urban areas in some cities by 2021; the operational design domain limitations for this system have not yet been determined.

3.2 Risks and opportunities

Use of these new mobility services can provide improved comfort of public transport, for example, by offering convenient and safe first-mile/last-mile services, the absence of solutions are main current deterrents from a wider modal shift away from the private car to (conventional) public transport using legacy modes. Also, through the use of shared mobility solutions, vehicle occupancy rates could be drastically increased, thus decreasing the number of vehicles within the network and freeing up capacity and urban spaces. In turn, this can then lead to the potential for less private car ownership (see box 8 for general key benefits of such systems and services).

But despite the potential positive aspects, some negative ones are also possible to arise if un-

Box 8 | Overview of shared mobility services



Key benefits include:

- First-mile/last-mile service
- Reduce traffic congestion
- Mitigate forms of pollution
- Reduced transport costs
- Improved efficiency
- Choice for no access to car
- Options for disabled

checked by appropriate regulatory responses, including the following specifically for AV fleets:

- A modal shift away from public transport, green modes, and active modes (such as cycling and walking) to single-occupancy ride-hailing.
- Induced traffic through the (temporary) increase in link or network capacity, which might encourage use of private cars and counteract modal shift.
- Travel time in automated vehicles might be perceived as more active time (working, relaxing), which could lead to accepting longer commuting time and thus more urban sprawl.
- Zero value of time leading to much larger travel demand and business models relying on empty (i.e. no human passengers) vehicles, thus decreasing average vehicle occupancy rates.
- Decreases in tax revenues, including parking fees, vehicle ownership fees, and vehicle registration fees, among others, due to the disruptive nature of this technology.

3.3 Role of the public sector

Options for decision-makers to actively manage the introduction of new mobility services and other innovative transport related business models may include incentives for high vehicle occupancy, either through access to priority high occupancy vehicle (HOV) lane infrastructure, or road user charging based not only on distance travelled, time, zones, fuels, and vehicle types, but also on the vehicle occupancy rates of individual vehicles.

Another critical policy area in this context is integrated infrastructure and land-use planning, whereby both are ideally always carried out in parallel; further mobility service specific points here include the constructive use of freed-up parking spaces, curb access for shared ride services, and even infrastructure changes for bikes and scooters.

Regulation of the ride-hailing industry might also have to be addressed in order to avoid or decrease the disruptive effects of the services vis-à-vis traditional legacy modes. Here a key element would be voluntary or mandated access to data on mobility behavior changes and modal shift, for regulators to judge the impact of these transport services.

Furthermore, policies that achieve pricing of transport services should also be considered as well of the use of private vehicles with pricing based on full externalities, including congestion issues. This can help create a level playing field financially. Measures to provide incentives in these cases include taxes, fees, or road user charging schemes, which have been in operation for some time in some cities and countries globally.

In addition, policies for labor market impacts might also have to be considered. In case of a quick and large uptake of vehicle automation in the transport sector, large number of professional drivers would be displaced. In this case, funding needs to be generated or be set aside for retraining and/or early retirement of drivers; this could be based on licenses for use of advanced vehicles.

Furthermore, the effect of competence needs to be also considered in this context. As there is a risk that only a small number of companies concentrate on a larger market share. In the AVs industry, we see very often mergers between technology, mobility services, and car manufacturers. And therefore it can be identified an increasingly vertical integration within the value chain; again requiting appropriate policy oversight.

Moreover, it should also be good practice to follow "The Shared Mobility Principles"[5], as established by mobility service industry pioneer Robin Chase:

1. We plan our cities and their mobility together.
2. We prioritize people over vehicles.
3. We support the shared and efficient use of vehicles, lanes, curbs, and land.
4. We engage with stakeholders.
5. We promote equity.
6. We lead the transition towards a zero-emission future and renewable energy.
7. We support fair user fees across all modes.
8. We aim for public benefits via open data.
9. We work towards integration and seamless connectivity.
10. We support that AVs in dense urban areas should be operated only in shared fleets.

There is a potential for shared AV services to drive new, efficient, high-quality urban development patterns with low car and low carbon characteristics and a high quality of life (for example, street space useable for children, etc.). AVs can also be part of economic development, particularly in the case of property development in urban areas. For example, in large urban areas in North America new high-end developments now often feature an "Uber waiting room" for residents.

Beyond these trends, there is also the potential for integration of new housing into mobility-as-a-service memberships and with specific facilities, like shared vehicle parking areas, among others. For AVs to be a part of the overall travel chains, fare integration is required, such as a prerequisite for last-mile solution, but also for door-to-door systems, which would not be the sole provider of mobility, but would compete with other modes and providers, based on different pricing regimes, levels of service, and other factors.

Different actors that may drive early uptake of these technologies can be identified. This includes industries (traditional car manufacturers, IT sector innovators, or partnerships of both) which push specific products and services into the market, the public sector based on transport needs, and —perhaps most importantly for the first highly visible implementation— individual champions with vision and a political agenda. In the past, demonstrations

5. Shared mobility principles for livable cities. Retrieved from: https://www.sharedmobilityprinciples.org/

have been driven more by research, industrial development, marketing needs and industrial policy, rather than in response to specific transport purposes or needs.

AV technology could entirely take over urban mobility (in some environments), but the more likely scenario is that it would contribute to the existing multimodal transport systems, with specific importance for the first-mile/last-mile feeder functions; thus improving the overall quality and comfort of services. Moreover, different operational environments would require different solutions; some of them better suited to AVs, some less. For example, dense cities might be more appropriate for high-capacity collective modes, but suburban areas might benefit from completely new transport options, as an alternative to the private car. AVs can become enablers in redefining streets and achieving more livable cities. Minimum parking requirements are today the standard in many cities, there is a chance to modify this with shared mobility modes. In the urban context, denser environments with payment-based management of parking spaces can further incentivize the uptake of rides sharing systems.

Potential negative effects of AV technology and shared mobility concepts need to be taken into account. The promise of significantly reduced congestion might well be reversed, instead of inducing traffic through lower prices for mobility and a release of latent demand. Such effects are typical of investments in new or upgraded road infrastructure, such as capacity increases tend to be short-lived, as travel behavior changes as a result of improved travel times, with people switching modes and routes, quickly leading to a return of similar congestion levels with the overall increase in vehicle-km travelled.

Another key concern is that if AVs provide door-to-door services and enable other activities to be done while travelling, it could lead to commuting time being considered useful rather than lost time. Therefore, it could derive on a strong influence on housing choices which could end up in a higher urban sprawl, with AVs allowing users to live further away from places of work, tolerating longer (but more useable) travel times.

Automation is thus likely to increase pressure on road space and the tendency for sprawl in the long term would make effective demand management (through road pricing, telecommuting, or mass transit investments) increasingly important. Fortunately, the same technology that facilitates automation also facilitates dynamic road pricing. Automation also highlights the importance of governments redoubling efforts to integrate land use and transport planning.

The expert discourse on implementation of vehicle automation for shared urban mobility applications often over-simplifies the situation, advocating a "one-size-fits-all" solution; but a series of factors would have a bearing on how such a system is to be designed in order to be accepted by the targeted users. Some of the geographical, societal, and cultural factors for AV implementation may include:

- Social, societal, and demographic factors.
- Economic level and income distributions.
- Car ownership levels and car culture.
- Existing layout, size, and density of the urban form.
- Characteristics of the built environment specific requirements for mega-cities.
- New cities, green-field and brown-field developments.
- Current transport modal provision and share legal and regulatory frameworks in place.
- Cultural aspects relating to: Perception of safety and trust.
    - IT and technology literacy.
    - Driver behavior.
    - Environmental awareness.
    - Views on privacy.

It is important to note in this context that none of these points; particularly not the views, customs, and perceptions of the public, are fixed, but rather have to be seen as being dynamic, changing based on various events and over time and generations/cohorts. Also, current trends need to be scrutinized in order to avoid drawing the wrong conclusions without a broader view.

One example is the observation that millennials in dense urban areas are increasingly moving from vehicle ownership to shared mobility schemes, potentially heralding the death of the privately owned car. But there is evidence that this cohort marries, settles down and has children considerably later than previous generations, and at that time there is then a move to car ownership; this additional information points to very different conclusions. Focusing on urban millennials who work in the information-based economy also ignores their counterparts in the vocational trades, the older generations and those who live in low-density suburban and rural areas, whose attitudes toward vehicle ownership are much less likely to change substantially.

The above considerations all point to the need for designing and implementing tailor-made solutions that take into account all local, regional, as well as national characteristics. Once the first systems emerge, a case-study based analysis would be able to take this important discussion forward, ideally leading to a best practice guides detailing the lessons learnt and helping to match specific solutions to specific types of local and wider challenges.

A widespread move to shared mobility is likely to occur in a more limited number of places in the absence of government intervention. As a result, adoption would depend on the effectiveness of regulation and other government interventions that influence the adoption path for AVs. In turn, there have been calls for governments to start taking preparatory action to avoid the negative consequences of a business as usual scenario. There are numerous regulatory options available to governments that wish to avoid the negative consequences of a business as usual scenario and capture the benefits of a shared mobility scenario. Critical measures here may include:

- Charging for the use of road space per mile, based on the marginal cost.
- Taxing vehicle travel.
- Levies for road travel in and around areas of congestion varying by:
    - Time of day.
    - Congestion levels.
    - Vehicle occupancy.
- Limiting public parking and/or charging for it at a commercial rate (that can vary by time of day).
- Limiting the number of vehicle registration permits and allocating them by auction.
- Reallocating parking space as pick up and drop off zones.

These measures target the price of individual mobility, aiming to internalize the cost of road transport. By requiring road users to pay the full costs of their road use, such as the costs of maintaining infrastructure or congestion, these measures would provide incentives for all road users to ration their road use more efficiently. Shared mobility services (especially multimodal, shared and last-mile services) would be more competitive under these regulatory options. Shared mobility users could flexibly shift between modes, split the increased costs with other users and avoid parking facilities. As a result, under these regulatory options, shared mobility services prices would likely increase by less than individual mobility prices. In turn, they would be more competitive with individual mobility.

Many of these options have been available to governments for a number of years and none are contingent upon AV deployment. For example, Singapore has had road pricing since 1998, London's congestion charge commenced in 2003 and Stockholm's congestion tax commenced in 2007. Where these options have been implemented, they have had positive impacts on congestion, provided funding for mass transit improvements and incentivized changes in consumer preferences to other, more efficient modes of transport.

However, they have also increased road transport costs to consumers, reduced the value of consumers' sunk investments in private vehicles and can be criticized for restricting freedom of movement and being inequitable to consumers who have poor access to other transport modes. As a result these are significant reforms that tend to be controversial and take substantial time to implement. For example, a congestion charge for London was first proposed in 1963, 40 years before it was implemented. They would also be more likely to obtain public acceptance in response to an existing problem, rather than in anticipation of problems that might arise in the future.

As a result, while they are theoretically economically elegant and an increasing number of jurisdictions are adopting them, implementing measures that seek to internalize the costs of transport would face substantial challenges in many jurisdictions where travelers are accustomed to widespread personal vehicle use, especially in advance of AV deployment.

Given the challenges in some jurisdictions, they may wish to consider actively encouraging a shift in consumer preferences towards shared mobility more than discouraging private personal vehicle usage with punitive measures (relying more on "carrots" than on "sticks"). Governments can use regulatory and policy measures to remove barriers and facilitate the expansion of shared mobility services, effectively lowering their price and making them more competitive with individual mobility.

Last-mile shared mobility services can be facilitated through better integration of fares and information across transport modes. Transit authorities can move away from closed-loop payment systems that require a specific card/ticket that they administer, to open loop payment systems that link to users' bank cards or mobile payment systems. Alternatively, they can integrate closed-loop payment systems with other shared mobility services.

For example, the Chicago Transit Authority (CTA) has integrated fares with IGO, a car-sharing service. Consumers can use the same fare card to use CTA's mass transit services and IGO's service. Similarly, apps such as Nimbler can provide consumers with directions that integrate different modes of shared mobility, such as bike and mass transit. Practices such as these make using shared mobility services easier and, in turn, more competitive with individual mobility. Ideally, they would be expanded to allow consumers to plan multimodal shared mobility trips, using real-time information and a single payment.

Equally, governments can remove existing barriers to shared mobility services. For example, California's Public Utilities Code prevents fares being levied on an individual basis, requiring them to be levied on the basis of vehicle mileage or time of use (CPUC §5401). Charging on an individual basis effectively prohibits ride splitting services, such as UberPool and Lyftline. The California State Legislature is currently amending legislation to remove this barrier.

All of the measures above can and, arguably, should be implemented prior to AV deployment. Doing so would assist in shifting consumers' preferences towards shared mobility before AV deployment further reduces the cost of individual mobility. In turn, this may make it easier for governments to implement more ambitious reforms, allowing them to capture the benefits of a shared mobility scenario and prevent the negative consequences of a business-as-usual scenario from arising, rather than requiring regulators to attempt to reverse them after the fact.

Moreover, specific recommendations regarding the management of curb access for new mobility services, in addition to pricing regimes, may include:

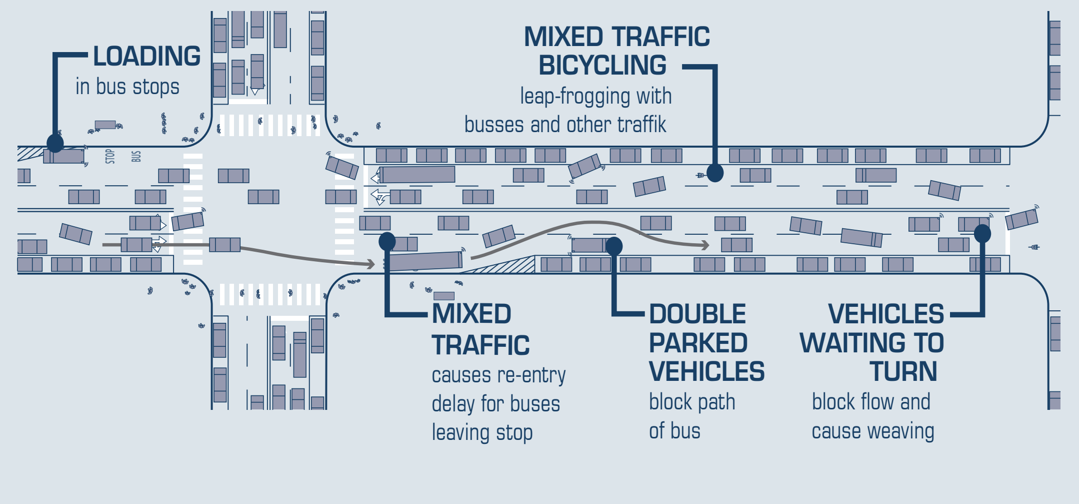
- Establishing a system of street designations according to their primary purpose.
- Anticipating and planning for the revenue impacts of shifting curb use from car parking to passenger pick-up and drop off.
- Making room for ride services at the curb where this fits strategic priorities.
- Building on or creating adjudication bodies to manage diverse demand for curb space in flexible ways and ultimately in real time.

- Helping develop common standards for encoding information about curb use.
- Rethinking streets and their curbs as flexible, self-adjusting spaces and plan accordingly.
- Managing curb space dynamically so it adapts to different uses and users.
- Establishing effective tracking and monitoring of overall transport activity, including ride services.

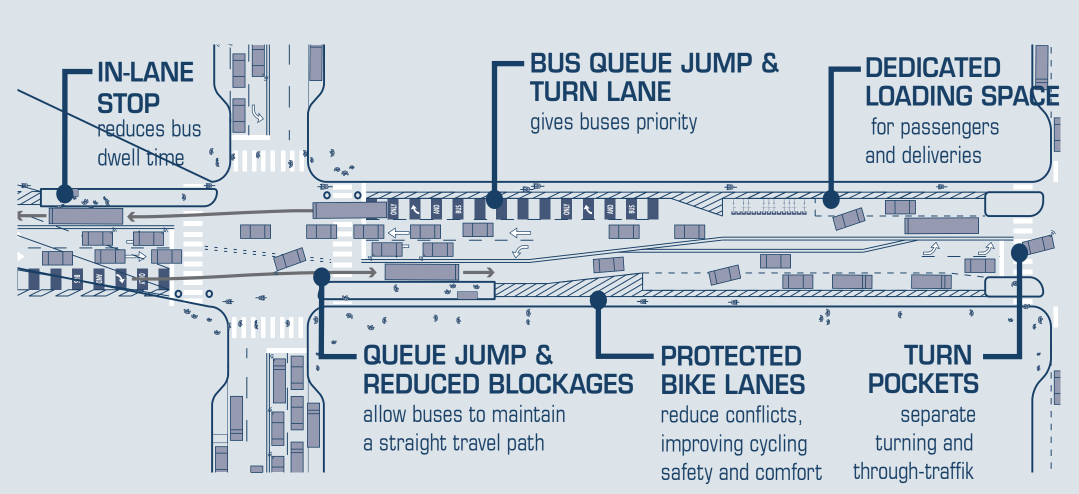
Box 9 shows recommendations by the National Association of City Transportation Officials (NACTO) for improving curb access in cities.

Box 9 | Recommendation for curb access in cities (NACTO)[6]

Before: Unorganized streets cause friction between vehicles and reduce transit reliability due to blockages.



After: Organizing a street and curbside allows more efficient traffic flow & operations for both transit and general traffic.



6. Curb appeal. Curbside management strategies for improving transit reliability, NACTO Transit Leadership Resource Paper, November 2017, retrieved from: https://nacto.org/wp-content/uploads/2017/11/NACTO-Curb-Appeal-Curbside-Management.pdf

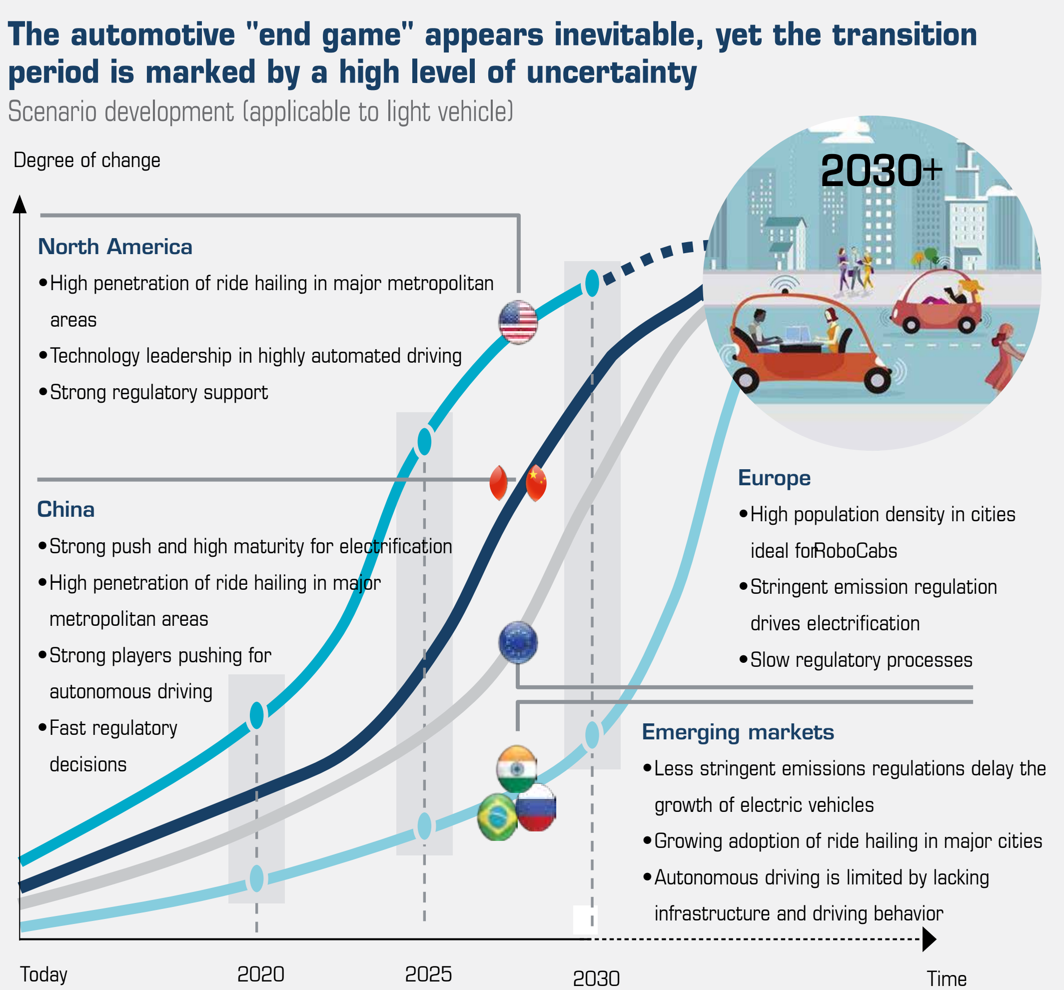
3.4 LAC county discussion

Specific issues from the Latin America and the Caribbean region include driver concerns over labor markets effects of vehicle automation in the absence of any government intervention. Also, the region is seen as a key new market for the ride-hailing industry, bringing with it likely further regulatory conflicts with these new players. Tailored policy solutions would thus have to be found.

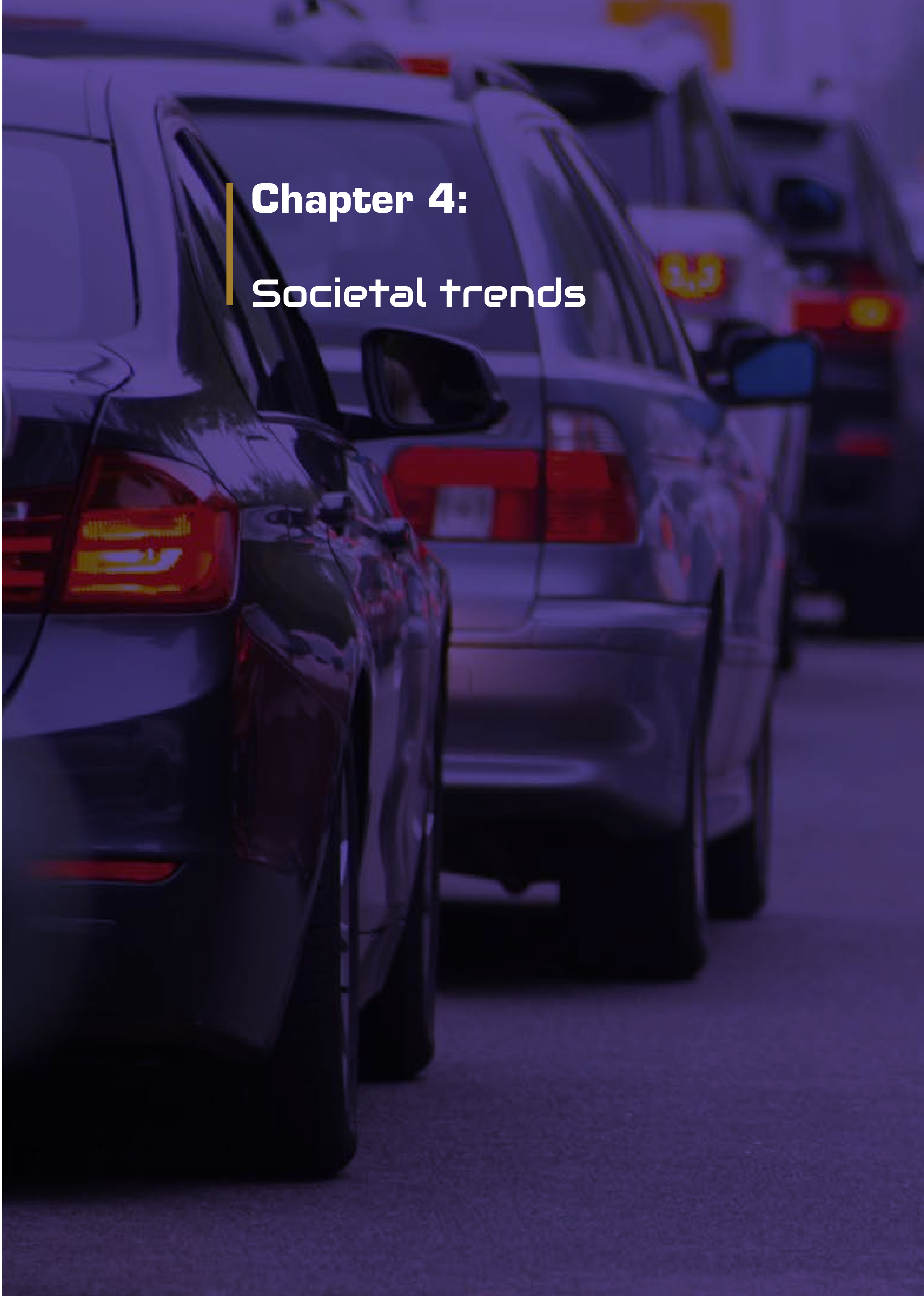
The effects of new mobility services on the LAC car industry also needs to be taken into consideration. A widespread move towards new mobility services and a corresponding decline in private car ownership would directly impact sales. The automotive industry needs, therefore, to be an active part of this development, operating their own shared mobility services and producing tailored vehicles.

Options here include building up conventional public transport before considering more advanced systems and technologies, ideally in parallel with establishing multimodal transport authorities on city or regional level, to operate such services in a coordinated manner. Furthermore, partnerships between cities and mobility service providers, particularly the ride-hailing industry, should be sought in order to achieve better regulatory compliance and to share data.

Box 10 | Regional variability of technology uptake (Roland Berger Study)[7]



7. C-ITS Platform Phase II chaired by the European Commission. Retrieved from: https://www.polisnetwork.eu/uploads/Modules/PublicDocuments/phase-ii---c-its-platform---draft-final-report---september-2017_v1.0.pdf



Chapter 4:

Societal trends

4.1 Definition of elements

Key societal trends, which can be observed to have a bearing on transport and mobility behavior, include lower car ownership levels in urban areas and for younger generations; and different mobility behavior compared to previous generations with the use of platforms, sharing, and social media, due to their ability and use of digital technology (see box 11). But of course only the emergence of the necessary mobility services (starting with the so-called "car clubs", early precursors of the current car sharing providers such as car2go or DriveNow, in the 1970s).

A significant aspect of digital platforms for mobility, which are enabled by big data analytics, is the question around data ownership and privacy. Whereas data privacy is very recently being governed in the EU by the General Data Protection Regulation (GDPR), legal frameworks in other parts of the world are less comprehensive. However, it is not only the legal framework that is relevant here, important factors for technology uptake and mobility choices can also be attitudes towards data privacy, data ownership, and access to personal data (see box 12).

4.2 Risks and opportunities

The societal trends described in the previous section can have many positive aspects on mobility, particularly on dense built-up urban areas. This includes the use of micromobility in addition to high-quality multimodal public transport. If managed well by policymakers, it can also achieve higher vehicle utilization, less congestion, and freed up parking; and it can be the basis for greener and more sustainable urban redevelopment. But there is a strong focus on built-up urban environment, with less solutions being offered for populations in more rural areas.

A key demographic in this context are millennials, the generation born in the 1980s and 1990 and thus came of age at the turn of the new millennium. In terms of mobility behavior, this cohort is often to be reported to not just see the private car not as a status symbol anymore, but to shun them altogether. Closer scrutiny of the data (see box below) gives a more nuanced picture. Millennials on average settle down and start a family later than earlier generations, but at that point often still own a private car. Car use, despite ownership, is less though and is seen more as one of many options in the multimodal transport supply.

4.3 Role of the public sector

Policymakers and regulators need to utilize the opportunities of the changes mobility behavior and attitudes of millennials. To accomplish this, they need to be given the appropriate framework for the mix of mobility solutions and be given easy access to all data and information required to make informed decisions regarding this subject. Data privacy protection policies need to be put in place, to provide security to them as consumers, but at the same time allow the tech sector sufficient flex-

Box 11 | Technology savviness of different generations[8]

Figure 1: US Online Adult's Self Reported "Digital Savvyness"

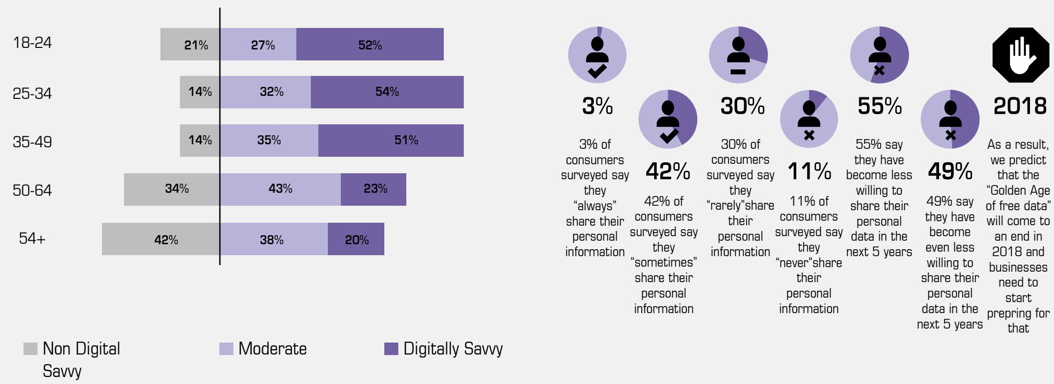


Figure 2: Consumer Attitudes to Online Data Collection Practices

% of global respondents indicating that this collection of personal information crosses the line from customization to invasion of privacy
June 2013

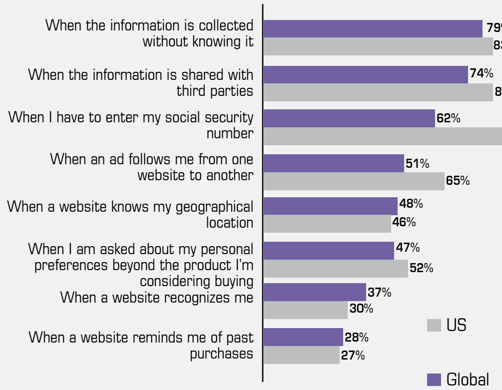
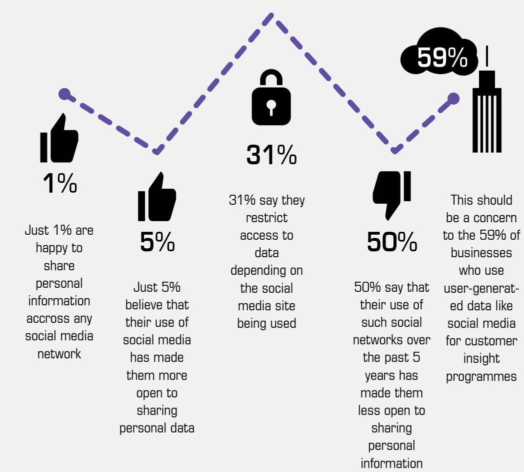


Figure 3: When it comes to using their social media data they are even more sensitive



8. US Online Adults' Self-Reported "Digital Savvy-Ness". Marketing Charts. Retrieved from: https://www.marketingcharts.com/digital-82314/attachment/adobedigitalinsights-us-online-adults-digitally-savvy-feb2018

ibility and opportunity to develop and market new data enable business models and opportunities.

This may require the transfer of certain traditionally public sector roles and responsibilities to the private sector. Here, vendor lock-in and a situation where there is not sufficient public sector oversight need to be avoided. Important requirements for the public sector in response to these developments relate to capacity building for their staff in the area of big data analytics, data science, and data privacy, in addition to building up their IT infrastructure.

4.4 LAC country discussion

It should also be noted that in LAC countries the private car is often still seen as an aspirational status symbol, with still low but rapidly rising car ownership levels; this is clearly in conflict with

Box 12 | Selected statistics on mobility behaviour of millennials[9]

Figure 1: Those who live alone or are parents living with children are most likely to live in or near "downtown"

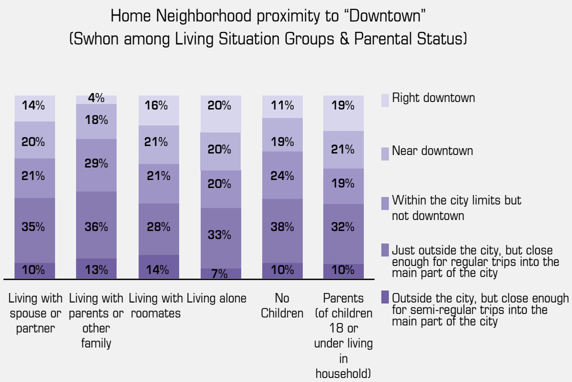


Figure 2: Millenials who are parents were more likely to have bought a car, but only slightly more likely to have moved to the suburbs tan non parents

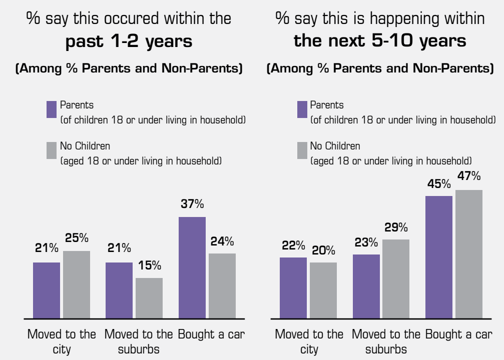


Figure 3: On an attitudinal level, millenial parents may be more likely to feel freedom in options for how they'd like to live - with or without a car, in an urban or suburban environment

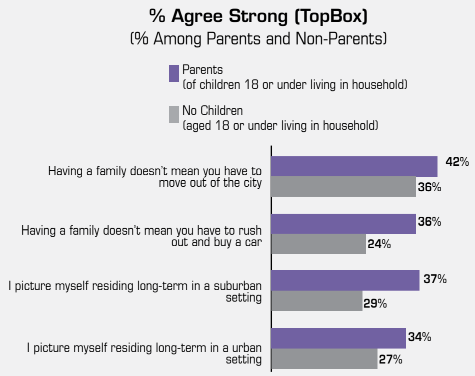


Figure 4: Millennial parents may be more likely to "opt-in" to car ownership, as part of a multimodal strategy to have options for getting around

	Parents	No kids
Q16 -How often do you use more than one transportation option for getting to a destination?		
	374	626
% use more than one transportation option for getting to a destination **daily**	43%	33%
S10 - How many cars are owned by people in your household, including yourself?	Parents	No kids
	374	626
Mean # of cars owned per household	1.7	1.46
Q19 - Which of these describe how your car fits your transportation routine?	Parents	No kids
	253	347
I can't get to the places I need to without a car (at least some of the times)	27%	36%

Millennial parents are more likely to be using multiple options on a daily basis.

They're more likely to have multiple cars in their household, but interestingly, among car owners, millennial parents were less likely to feel they have to have a car to get to places they need.

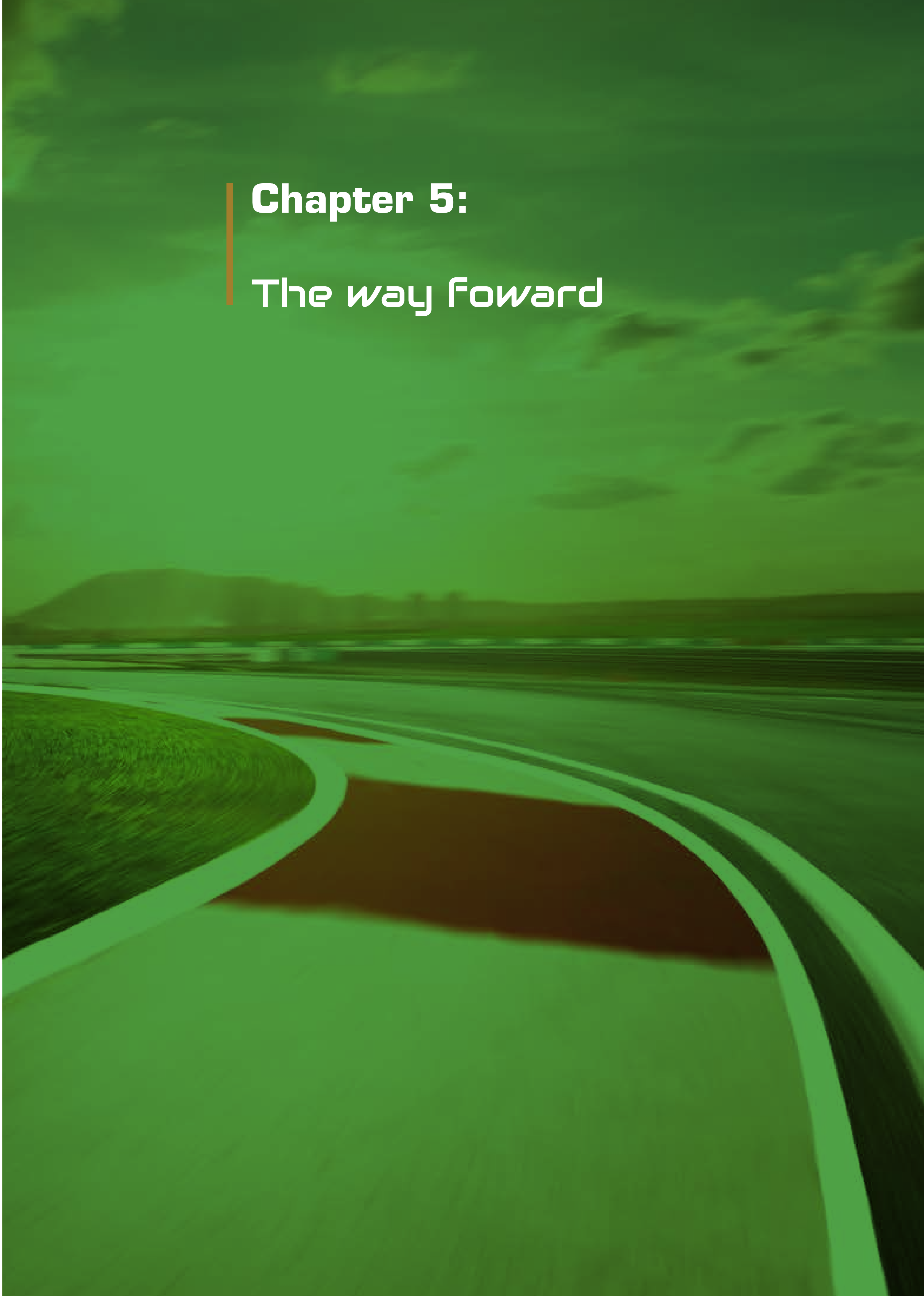
9. Retrieved from: https://www.aarp.org/content/dam/aarp/livable-communities/old-learn/transportation/apta-millennials-and-mobility.pdf

the societal attitudes and behavior of the millennial cohort we are witnessing in other parts of the world. If decision-makers want to see similar developments in the area, campaigns to change "hearts and minds" might be necessary, pointing out the negative effects of private car ownership and use.

But this would only be possible if the necessary alternative mobility options, including existing traditional public transport as well as new players, are readily in place. There are signs of not only quick uptake of private car ownership, but also of mobile internet access in the region, so this might be a key opportunity for changes in attitudes. But should these developments slow down car purchases, the effects of this on the local industry and economy also need to be taken into consideration; in addition to the implications of the regional economic differences across LAC countries.

Chapter 5:

The way foward



5.1 Summing up and policy context

We are now in the midst of a highly transformative phase for transport and mobility. Vehicle automation —and the various forms of shared mobility services potentially enabled by them— are now a clear trend, but there are varying expert opinions on projected time scales, the level of disruption it would cause, the technology options, and use cases involved. But at the same time positive and negative scenarios are possible and policymakers need to prepare their response. These developments require a look at government roles and responsibilities. Policymakers need to manage the transition period. But at the same time they also should provide sufficient flexibility during uncertainty, locking-in benefits while avoiding potential risks. Key tools here are legal and regulatory frameworks.

Many potential positive effects of vehicle automation are being quoted, including improved road safety levels, decreased vehicle emissions, and increased network capacity. Likewise, the emergence of related mobility services also holds the promise for even larger benefits for society as a whole as well as on the city level. This is based on the concept of shared mobility, which relates to both shared access to vehicles and shared use of them, such as a move from vehicle ownership to vehicle "user-ship". Through these concepts vehicle occupancy rates could be drastically increased, decreasing the number of vehicles within the network and thus freeing up capacity and urban spaces.

But at the same time some negative effects could also be envisaged, including network capacity gains leading to induced traffic, zero marginal cost leading to increased demand and trip numbers, a modal shift away from public transport and other green modes, the ability of using travel time more productively leading to longer trips as people move further away from urban centers (which in turn then leads to further urban sprawl), potentially huge fleets of empty vehicles running errands (for example, picking up the dry cleaning, your shopping, or a take-away) and thus generating much larger congestion levels, and wider labor market effects.

Governments around the world are investing in research and development (R&D) and demonstration of near market-ready systems, showcasing their ambitions for leadership in this space. Furthermore, emerging companies with a much stronger IT focus on technical background and leadership mentality are aggressively pushing into the market. Vehicle automation is thus part of the concepts of the sharing economy and disruptive innovation, but the "road" ahead for AVs is still far from certain. The car industry appears to be betting a slow and evolutionary process with little transformation, for which they have full control. The disruptors, on the other hand, are predicting much larger transformation and much faster implementation of new services.

This discussion paper covered 3 key trends affecting the future of mobility: technology trends (automation, connectivity, and electrification), service trends (shared ownership, shared use, and mobility platforms), and societal trends (car ownership, mobility behavior, and privacy attitude). For each trend the following analysis steps were followed: definition of elements, risks and opportunities, the role of the public sector, and a Latin America and the Caribbean (LAC) country discussion. The section

below summarizes the analysis of the key policy issues emerging, allowing a cross comparison among the crucial megatrends and the main issues of the analysis framework. This is followed by a section on specific government actions for appropriately guiding the development of trends.

5.2 Overview of policy analysis results

A. Technology trends

1. Definition of elements	2. Risks and opportunities
• Clean vehicle technology and fuels • Assistance and full automation • Communication between vehicles • Incident warning functionalities • Scheduling for fleet-based systems • Vehicle charging infrastructure	• Improved road safety performance • But also new accident scenarios • Minor environmental impact (AVs) • Large pollution improvements (EVs) • Minor network/link capacity gains • Much larger effects of mobility services

3. Role of the public sector	4. LAC country discussion
• Financial incentives for cleaner cars • Industry standards for vehicle safety • Funding for comms and for charging • Flexible regulation for saving innovation • Address decreasing fuel tax income • Nudges for enabling mobility services	• Less but rising vehicle ownership rates • Older fleet and less technology maturity • OEM concerns over rising product costs • Higher importance of driver assistance • Road safety levels are a key concern • Realistic view on AVs and EVs necessary

B. Service trends

1. Definition of elements	2. Risks and opportunities
• Emergence of new mobility services • Shared use and ownership of vehicles • App-based ride-hailing providers • Mobility service platforms (MaaS) • New modes (scooters, dockless) • Low-speed first-/ last-mile shuttles	• Improved comfort of public transport • Potential for less private car ownership • But also modal shift from green modes • Induced traffic and more urban sprawl • Zero value of time and empty vehicles • Labor market effects of automation

3. Role of the public sector	4. LAC country discussion
• Incentives for high vehicle occupancy • Infrastructure and land-use planning • Regulation of the ride-hailing industry • Access to data on mobility changes • Pricing based on full externalities • Policies for labor market impacts	• Driver concern over labor markets • Key new market for ride-hailing industry • Regulatory conflicts with new players • Build up conventional public transport • Multimodal transport authority • Partnership between city and provider

C. Societal trends	
1. Definition of elements	**2. Risks and opportunities**
• Lower car ownership levels in urban areas and for younger generations • Different mobility behavior with use of platforms, sharing, social media • Ability and use of digital technology but different views on privacy	• Use of micromobility in addition to high-quality multimodal public transport • High vehicle utilization, less congestion, freed up parking, urban redevelopment • Focus on built-up urban environment, less solutions in more rural areas
3. Role of the public sector	**4. LAC country discussion**
• Provide privacy protection policies • Public->private responsibility transfer • Avoid any vendor lock-in • Develop flexible mobility regulation • Innovation while protecting safety • Capacity building for data science	• Car as an aspirational status symbol • Campaigns to change behavior • But effect on local OEMs and industry • Quick uptake of mobile internet access • Consider regional economic differences • Existing public transport and expansion

Based on the above analysis results, it is possible to formulate the following propositions, which — under the right policy guidance— constitute an optimal use of emerging technologies with a realistic technology readiness until the projected timescale of this analysis (year 2030):

i. A wide uptake of fully-electric vehicles, both for private cars and for commercial fleets (passenger and freight transport), would improve air quality in urban areas.

ii. Implementation of connectivity technology between vehicles and infrastructure would have a positive impact on road safety, based on incident information and warning.

iii. Uptake of lower levels of vehicle automation (assistance systems) would have a positive impact on road safety levels, based on accident avoidance and reduction of impacts.

iv. The consumer uptake of various available new shared mobility concepts would allow a wide modal shift from private car use to more sustainable modes of transport.

v. A changing mind-set, particularly amongst the younger generation and in urban areas, would see a move away from private car ownership, both as a necessity or a status symbol.

For these 5 policy propositions, the necessary targeted government actions and responses are developed in the following section. This includes the description of requirements, risks, opportunities, deployment barriers, and technology readiness.

5.3 Targeted government actions

Proposition i: A wide uptake of fully-electric vehicles, both for private cars and for commercial fleets (passenger and freight transport), would improve air quality and reduce noise emissions.

Requirements

- Tax breaks to buy electric vehicles to encourage consumer uptake and industry compliance.
- Policy support for a comprehensive build-up of the necessary vehicle charging infrastructure.
- In the short term, find consensus for industry standards on compatible charging technology.
- Market education (both private and fleets) to dispel the often quoted "range anxiety" issue.
- Policy measures to address the loss of public income through decreased fuel tax revenues.
- Use of urban access control measures based on the environmental performance of vehicles.
- Wider stakeholder engagement (industry, user, policy level) to build a cooperative environment.

Risks

- Tax breaks leading to only uptake of hybrid vehicles, which are rarely used in electric mode.
- Mass technology uptake leading to large and very immediate decreases in the fuel tax revenues.

Opportunities

- Large positive environmental impacts achieved at the point of use of electric vehicle fleets.
- Improved livability of urban spaces through decreased emissions and noise pollution.
- Batteries of electric vehicles could also be used as additional storage for the national grid.

Deployment barriers

- Push-back from car manufacturers concerned about investment in new production facilities.
- Lack of technology standardization and interoperability making EVs less viable financially.
- Unresolved vehicle charging technology and standards hindering wider technology uptake.

Technology readiness

- Private fully-electric vehicles have already been on the market in many regions for years (most notably Tesla), hybrid vehicles for even longer; sales generally are increasing.
- Bus and urban delivery fleets are among the first where a shift to electric vehicles can be observed, often through a combination of tax breaks and contribution to sustainability.
- Proprietary charging infrastructure exists (again most notably the Tesla Super-Charger network, but Porsche also announced to be in the process of building up their own infrastructure).
- For vehicle fleets, different charging concepts exist, including battery swapping at depots, etc.

Proposition ii: Implementation of connectivity technology between vehicles and infrastructure would have a positive impact on road safety, based on incident information and warning.

Requirements

- Policy support for a comprehensive technology-neutral build-up of the support infrastructure.
- In the short term, find consensus for technology options on mobile communication (5G) or DSRC.
- Tax breaks to buy equipped vehicles to encourage consumer uptake and industry compliance.
- Formulation of industry standards for vehicles and linkages of services with insurance policies.
- Policies such as eCall in the EU in order to make communication technology mandatory in new cars.
- Technologies and processes to guarantee data security in all new communication channels.
- Broader stakeholder engagement (industry, user, policy level) to build a cooperative environment.

Risks

- Uptake of road safety relevant services only in high-end vehicles not contributing to wider good.
- Communication networks will be under threat vis-à-vis cyber-crimes and privacy protection.
- Solely relying on the private sector to build up infrastructure can leave public sector vulnerable.

Opportunities

- Increasing road safety levels based on equipped vehicles being able to "look around curves".
- Can be implemented as part of a more comprehensive national ITS strategy (for example, similar to C-ITS in the EU).
- Better enforcement of regulations (for example, dynamic pricing) through data collection and exchange.

Deployment barriers

- Push-back from car manufacturers concerned about decreased vehicles sales with higher costs.
- Unresolved technology discussion hindering wider service uptake/infrastructure deployment.
- Missing public budgets to support the build-up of the necessary communication infrastructure .

Technology readiness

- DSRC technology is tried and tested, but requires the built-up of additional communication infrastructure (for example beacons), and also utilizes non-state-of-the-art technology.
- Once built up, mobile communication (5G) would not require additional communication infrastructure, but as a technology is only now nearing necessary maturity level.
- Proprietary closed in-car warning and information systems are emerging on the market, in the luxury segment, as with other ADAS technology "trickle-down" to lower segments likely.
- This is also part of the wider developing technology discussion on the Internet of Things, where this might well be a very tangible first technology implementation example.

Proposition iii: Uptake of lower levels of vehicle automation (assistance systems) would have a positive impact on road safety levels, based on accident avoidance and reduction of impacts.

Requirements

- Tax breaks to buy equipped vehicles to encourage consumer uptake and industry compliance.
- Support of international bodies formulating vehicle regulations to address these functionalities.
- Consider mandatory minimum road safety-relevant assistance functions in the new vehicles.
- Policies such as eCall in the EU in order to make minimum safety systems mandatory in new cars.
- Road safety campaign (such as NCAP) disseminating the effectiveness of assistance systems.
- Broader stakeholder engagement (industry, user, policy level) to build a cooperative environment.

Risks

- Uptake of road safety-relevant services only in high-end vehicles not contributing to wider good.
- New automated vehicle behavior relating to new accident scenarios with vulnerable users.

Opportunities

- Increasing road safety levels based on equipped vehicles decreasing the impacts of driver errors.
- Much larger return on investment compared to using less tested and less ready full automation.
- Part of industry-wide (vehicle manufacturers) efforts to improve standards of new vehicles sold.

Deployment barriers

- Push-back from car manufacturers concerned about decreased vehicles sales with higher costs.
- Slow regulatory response to the new in-vehicle technologies can hinder the system uptake.
- The general public not perceiving improved road safety as a motivation for higher car prices.

Technology readiness

- Advanced driver assistance functionalities (such as SAE levels 1-3) are already on the market in some regions and for some car manufacturers (for higher assistance levels notably the Tesla Highway Autopilot); research and development in this space is intense.
- Proprietary advanced driver assistance systems are thus emerging on the market, in the luxury segment, as with earlier examples "trickle-down" to lower segments likely; a focus here should be on the most widely available and thus low-cost systems.
- Much of the current discussion on vehicle automation centers on the highest levels of automation (such as SAE levels 4-5) in terms of research and development funding, here the technology readiness is likely to be much further off.

Proposition iv: The consumer uptake of various available new shared mobility concepts would allow a wide modal shift from private car use to more sustainable modes of transport.

Requirements

- Campaigns to educate the public on the environmental benefits of using shared mobility services.
- Setting up partnerships between new mobility providers, cities, and legacy transport operators.
- Co-design of the shared mobility services together with end-users and tailored to local situations.
- Consider policies (including pricing mechanisms) to provide nudges towards shared mobility.
- Mandate data access for regulators in order to be able to analyze modal shift effects occurring.
- Provide the necessary infrastructure and policies to support shared mobility use, for example, managed curb access through various measures, such as pricing, access control, design measures, etc.

Risks

- Unintentional shift from public transport and active modes to single-occupancy ride-hailing.
- Outsourcing of mobility as a public sector task to the private sector, might risk loss of oversight.
- Global expansion of increasing mobility service bundles can result in small number of platforms.

Opportunities

- Business models and services, which encourage shared use or ownership of vehicles.
- Can enable a modal shift to more sustainable and active modes of transport with right policies.
- Increase vehicle occupancy rates and thus decrease the number of vehicles in the network.
- Basis for lowering car ownership levels through vastly improved mobility choices in urban areas.
- Freeing up spaces in urban areas for more sustainable and citizen-friendly developments.
- Moving from parking management to managed curb access in urban development and policy.

Deployment barriers

- Push-back from car manufacturers concerned about decreased vehicles sales with higher costs.
- Unresolved technology discussion hindering wider service uptake/ infrastructure deployment.
- Missing public budgets to support the build-up of the necessary communication infrastructure.

Technology readiness

- Many companies providing shared mobility services have been in the market for a number of years already, including Transportation Network Companies (TNC)/ride-hailing/e-hailing (Uber, Didi, Lyft, etc.), car-sharing (DriveNow, Car2Go, etc.), and dock-less electric bike or scooter sharing (Lime, Bird, etc.); these are expanding aggressively globally.
- Many of these new shared mobility providers are, to varying extents (ranging from the purely conceptual stage to active pre-service rollout public testing, for example, Waymo or Cruise Automation), considering the use of highly automated vehicles (SAE levels 4-5) to further improve the efficiency and public appeal of their offering; here technology readiness is likely further off.

Proposition v: A changing mind-set, particularly amongst the younger generation and in urban areas, would see a move away from private car ownership, both as a necessity or a status symbol.

Requirements

- Tax breaks to buy equipped vehicles to encourage consumer uptake and industry compliance.
- Support of international bodies formulating vehicle regulations to address these functionalities.
- Consider mandatory minimum road safety-relevant assistance functions in the new vehicles.
- Policies such as eCall in the EU in order to make minimum safety systems mandatory in new cars.
- Road safety campaign (such as NCAP) disseminating the effectiveness of assistance systems.
- Broader stakeholder engagement (industry, user, policy level) to build a cooperative environment.

Risks

- Uptake of road safety-relevant services only in high-end vehicles not contributing to wider good.
- New automated vehicle behavior relating to new accident scenarios with vulnerable users.

Opportunities

- Large positive environmental impacts achieved at the point of use of electric vehicle fleets.
- Improved livability of urban spaces through decreased emissions and noise pollution.
- Batteries of electric vehicles could also be used as additional storage for the national grid.

Deployment barriers

- Increasing road safety levels based on equipped vehicles decreasing the impacts of driver errors.
- Much larger return on investment compared to using less tested and less ready full automation.
- Part of industry-wide (vehicle manufacturers) efforts to improve standards of new vehicles sold.

Technology readiness

- Advanced driver assistance functionalities (such as SAE levels 1-3) are already on the market in some regions and for some car manufacturers (for higher assistance levels notably the Tesla Highway Autopilot); research and development in this space is intense.
- Proprietary advanced driver assistance systems are thus emerging on the market, in the luxury segment, as with earlier examples "trickle-down" to lower segments likely; a focus here should be on the most widely available and thus low-cost systems.
- Much of the current discussion on vehicle automation centers on the highest levels of automation (such as SAE levels 4-5) in terms of research and development funding, here the technology readiness is likely to be much further off.

5.4 Concluding discussion and final remarks

The recommendations and insights in the sections above should be seen as an easily accessible "toolbox" for policymakers in the region to assist with their policy formulation to guide the development of new mobility services in the most appropriate manner. But it might be worthwhile to inject a note of caution at this. Attempting to look into the crystal ball to see what the future might hold for transport and mobility, either the disruptive and gig economy enabled mobility revolution is upon us, or the rumors of the death of the private car are greatly exaggerated; it is thus important to distinguish between hype and uncertainties going forward.

Some current mobility services are yet to make a profit or even to move from internally subsidized to full market prices, while a carefully orchestrated media hype successfully brings in wave after wave of new venture capital, leading to astronomical valuations of some businesses. So while both disruptive and transformative effects of new mobility service models can clearly been seen for a few years already, some future predictions regarding size and speed of service uptake, modal shift, or car ownerships levels clearly have to be taken with the proverbial grain of salt. This further necessitates flexible data-driven governance models, which can proactively manage mobility of the future —an industry in flux!

In addition, there are also still some remaining research and development requirements for (full/4-5) automated vehicles, before mass deployment can be envisioned from a technology point of view. These include some specific technology development in the area of sensors and artificial intelligence (AI), in order to enable safe vehicle operation in all weather conditions and in complex urban situations. Furthermore, the relationship with existing multimodal public transport in terms of transport policy and the effects on urban planning and policy and ways to communicate to the public would need to be researched.

References

Botsman, R., Rogers, R. (2011), *What's mine is yours: how collaborative consumption is changing the way we live* (Rev. and updated ed.), Collins.

Hook, L. (2016), Review of the Sharing Economy, *Financial Times* (Retrieved 9 March 2018)

Sundararajan, A. (2013), From Zipcar to the Sharing Economy, *Harvard Business Review* (Retrieved 9 March 2018)

Shaheen, S. Cohen, A. and Zohdy, I. (2016), *Shared mobility: current practices and guiding principles*, US Federal Highway Administration, Washington DC

Christensen, C. M. (1997), *The innovator's dilemma: when new technologies cause great firms to fail*, Harvard Business School Press

TRB (2017), *Transit Cooperative Research Program (TCRP) Report 188: Shared Mobility and the Transformation of Public Transit*

McKinsey & Company (2015), *Report, Urban mobility at a tipping point*

ITF (2016a), *CPB Report*, Data-Driven Transport Policy

ITF (2016b), *CPB Report*, App-Based Ride and Taxi Services: Principles for Regulation

ITF (2017), *CPB Report*, Data-led Governance of Road Freight Transport - Improving compliance

ITF (2017b), *Managing the Transition to Driverless Road Freight Transport*

CPUC (2013), *California Public Utilities Commission*, Press Release

SAE (2016), Society of Automotive Engineers, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, J3016_201609

SAE (2018), Society of Automotive Engineers, *Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies*, J3163

Walker-Smith, B. (2014), *Automated vehicles are probably legal in the United States*, 1 Tex. A & M L. Rev. 411.

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