Commission for
Territorial Cohesion Policy
and EU Budget

State of play of connected and automated driving and future challenges and opportunities for Europe's Cities and Regions

Contents

List of Figures and Tables

Abbreviations

ACEA	Association des Constructeurs Européens d'Automobiles (European Automobile Manufacturers' Association)
BEUR	Billion Euro
CAM	Connected and Automated Mobility
C-ACC	Cooperative Adaptive Cruise Control
EC	European Commission
ERTRAC	European Road Transport Research Advisory Council
EU	European Union
GAO	United States Government Accountability Office (GAO)
GDPR	General Data Protection Regulation
GHG	Greenhouse gas
GVA	Gross Value added
ICT	Information and communication technologies
LRA	Local and Regional Authorities
MEUR	Million Euro
MS	(European Union) Member State
Mtoe	Million tonnes of oil equivalent
PPP	Public-Private Partnership
PRT	Personal rapid transit
PSC	Public service contract
PSO	Public service obligations
RTDI	Research, Technical Development and Innovation
SAE	Society of Automotive Engineers
SGI	Services of general interest

Executive Summary

The development pathway towards Connected Automated Mobility (CAM) in the EU will be shaped by technology development as well as regulatory policies which will have to consider the following aspects:

- **Economic competitiveness** (which from a European perspective relies to a significant extent on technical harmonisation at a global scale);

- **Environmental aspects**: the trends towards urbanisation across Europe as well as the global race for primary energy sources puts a huge question mark to the prolongation of current developments in transport.

- **Road safety** as one of the likely beneficial effects of CAM; but the pathway to levels 4 and 5 in CAM – with an expanding number of test beds in real traffic – will require flanking measures which might impose considerable investment needs for LRA.

- **Interoperability** of the systems and comparable safety standards which is likely to pose considerable challenges across Europe when it comes to traffic management systems.

- **Cross-border cooperation**: concerning testing, traffic management systems and cross-border on-demand services.

Local and Regional Authorities (LRA) have a multi-dimensional role in transport policy on their territories since they are:

- developing local and influencing regional and national transport policies,
- enforcing traffic rules,
- providing infrastructure,
- providing transport services,
- providing Services of General Interest (SGIs) including transport.

Thus, one can see that CAM will affect several policy fields. From the perspective of LRA it will pose new requirements, such as for transport planning and infrastructure endowments. It will lead to new perspectives on legal issues and the need to adjust legal frameworks accordingly and it will open new opportunities for cost-efficient on-demand services or provision of certain SGIs.

As the EC pointed out in its recent Communication, a flexible policy and legislative approach will be necessary, continuously monitoring and taking into account technical development and field test results. Even if the roadmap for

widespread introduction of CAM systems is difficult to foresee – and a long period of co-existence of automated and non-automated vehicles is probable – it is highly likely that such systems will come and have considerable impact on LRA.

- Since CAM is labelled as transformative technology, continuous **monitoring of technology developments** is recommended.

- From the perspective of LRA the aspect of corresponding **requirements and developments in infrastructure** is decisive.

- In order to provide for **information** requirements of LRA concerning CAM, guidelines or a system of info points at national or EU level could be an option.

- LRA should bring in their point of view in **consultations** at national or EU level on future policy and legal steps.

- LRA as (collectively) largest road infrastructure managers play a key role in the **implementation** of CAM systems. LRA will also be decisive for the **acceptance** of CAM systems.

- LRA face additional **funding** requirements, mainly for upgrade and maintenance of road and digital infrastructure. Additional liability risks might have to be catered for, leading to additional **costs**.

Introduction

Transportation, connectivity, accessibility, mobility – many terms point at a range of different perspectives on the phenomenon of transport. Mobility is essentially a basic human need and in economic terms transport infrastructure has to be considered as a conditio sine qua non for any kind of activity.

In the past decade the so-called digital revolution has started to pervade road as well as rail transport meaning an increasing use of digital technologies in vehicle technology and – on the part of infrastructure – in traffic management, control and information systems.

In vehicle technology digital developments started off with engine management and exhaust fume control systems, refined safety equipment and information systems. The current pathway in technology development should lead via assisted and connected driving towards automated mobility. These trends basically apply to road and rail transport.

In road transport these technologies are also labelled as being potentially 'disruptive', which next to the technological break-through also signals expectably significant impact on societal developments. In road transport additional developments have been triggered off which are not necessarily linked to Connected and Automated Mobility (CAM) but are widely considered as intertwined development trends. These are:

- E-mobility, i.e. electric motors as single or assisting drive technology for cars and two-wheelers;
- Sharing economy and new forms of on-demand-services.

The automotive industry is ranked as a key manufacturing industry in the EU – the automotive sector accounts for about 13.3 million jobs, thereof 3.4 in car manufacturing; it is one of the leading export industries accounting for significant investment in RTDI.[1] A leading role in CAM is considered as a pre-requisite for the sustained competitiveness of the European automotive industries.

Finally, the aspects of resource consumption, environment protection and mitigation of climate change have to be considered as overarching issues which might impose stricter regulatory policies on transport in the upcoming decades. It is transport, households and services (mainly heating and cooling of buildings) as well as industries which account for the bulk of energy consumption in the

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[1] All data according to the European Automobile Manufacturers' Association (ACEA); according to ACEA the automotive industry is the largest private investor in R&D in Europe, with almost €54 billion invested annually.

EU. Primary energy consumption for road transport has constantly risen in past decades[2]. Thus, any serious attempts towards more sustainable pathways to economy have to focus on reduced resource consumption in road transport.

It is important to see that technological innovation and policy-making are interlinked processes. From the perspective of policy-makers mainly two fundamental policy options exist, i.e.

- Incentive policies, in case of CAM foremost public support to research, development, technology and innovation (RDTI), i.e. to vehicle technologies but also supportive respectively 'facilitating' technologies in traffic management systems;

- Regulatory policies, in case of CAM foremost legislation on traffic and licensing, liability as well as vehicle and infrastructure technology standards.

Policy-makers also have to care about the acceptance of new technologies. Several polls on acceptance of driverless cars indicate that a majority might be willing to use such vehicles.

With the Amsterdam Declaration (2016) it was underlined that the EU needs a shared strategy on connected and automated driving. Traffic and thus also CAM happens on territories managed by Local and Regional Authorities – therefore such a strategy has to take their perspective into account.

Scope of the Report

The Study seeks to provide a tentative outline on the main challenges and opportunities for Local and Regional Authorities (LRA) related to Connected Automated Mobility (CAM). It focusses on CAM in road transport, i.e. on transport with cars, lorries and busses, addressing passenger as well as freight transport. CAM – as potentially disruptive technology – is expected to trigger many developments with economic, social and environmental impacts. Consequently, the Study seeks to address the range of issues to be considered from the perspective of LRA in order to support a debate on important aspects for technology monitoring in the upcoming years.

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[2] Cf. Eurostat 2017; Final energy consumption in transport from 284.4 Mtoe (1990) to 358.6 Mtoe in 2015 (next to road transport it has been aviation which accounted for the largest increase); for household and services final energy consumption rose from 429.7 Mtoe (1990) to 450.6 Mtoe in 2015; share of renewable sources in transport in 2015 stood at 6.7%.

1 State of play of the role of Connected and Automated Mobility (CAM) in the EU and the world

Connected and Automated Mobility (CAM) is considered as one of the major future industrial technologies. In some reports it is labelled as a transformative[3] or even a disruptive technology, revealing potentialities to significantly change human behaviour. As a matter of fact, it is an economic challenge for one of Europe's major industries to maintain its role in the leading-edge technologies linked to CAM and to be able to influence the ongoing development process:

Today's automotive industry is at a turning point: it must embrace the upcoming digital revolution, automated and connected driving, environmental challenges (such as climate goals), societal changes and growing globalisation (GEAR 2030, Final Report)[4].

In more technical terms ACEA, the Association of European Automobile Manufacturers, defines Connected and Automated Driving (CAM) as follows:[5]

- Connected vehicles can exchange information wirelessly with other vehicles and infrastructure, but also with the vehicle manufacturer or third-party service providers.

- Automated vehicles, on the other hand, are vehicles in which at least some aspects of safety-critical control functions occur without direct driver input.

The commonly used classification framework for CAM has been set up by the Society of Automotive Engineers in its standard SAE J3016[6]. The below table gives an overview:

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[3] Cf. Greater Anna Arbor Region, 2017, p. 9.
[4] GEAR 2017, p. 3.
[5] https://www.acea.be/industry-topics/tag/category/connected-and-automated-driving
[6] Available under ++https://www.sae.org/standards/content/j3016_201806/

Table 1. SAE automation levels

SAE Automation Category	Vehicle Function	Driver
Human driver monitors the driving environment.		
Level 0	Human driver does everything.	Human steers
Level 1	An automated system in the vehicle can sometimes assist the human driver conduct some parts of driving.	
Level 2	An automated system can conduct some parts of driving, while the human driver continues to monitor the driving environment and performs most of the driving.	Human partly leaves steering to the car
Automated driving system monitors the driving environment.		
Level 3	An automated system can conduct some of the driving and monitor the driving environment in some instances, but the human driver must be ready to take back control if necessary.	
Level 4	An automated system conducts the driving and monitors the driving environment, without human interference, but this level operates only in certain environments and conditions.	Car steers
Level 5	The automated system performs all driving tasks, under all conditions that a human driver could.	

Sources: SAE, Bill Canis, ERTRAC, European Commission[7].

Vehicles available on the market today correspond to Levels 1 and 2[8]. In many countries all over the world, test runs and pilot projects with higher level CAM are carried out at the moment, often led by car manufacturers or IT companies – with USA and DE as leading countries. Many countries are about to adopt legislation in order to enable test runs of automated vehicles. In the USA, accidents involving self-driving cars of Uber (2018) and Tesla (2016, 2018) caused extensive media coverage. Besides the test runs with passenger cars, public transport projects, mainly with minibuses, have to be mentioned since these developments might be of particular interest for LRA.

Concerning public urban transport, two main development paths can be identified[9]:

■ Personal Rapid Transit (PRT) including Urban Shuttles for smaller urban mobility vehicles primarily for transport of people, for last-mile use, but potentially also for longer distances on confined, dedicated and open roads – these systems are not in the focus of the study.

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[7] Congress 2018, p. 2; ERTRAC 2017, p. 5; EC 2018, p. 3.
[8] Congress 2018, p. 2.
[9] ERTRAC 2017, p. 10. ERTRAC 2017, p. 5, points out that a Level 5 system has to be able to automatically drive under all road and environmental conditions. If the automated system is confined to a certain area, it is a Level 4 system.

- City-buses and coaches with various types of automated functionality like driver assistance, bus-stop automation, bus-platooning, traffic-jam assist on confined, dedicated and open roads.

Main industry **drivers** towards the development and introduction of CAM are[10]:

- Technological progress (new materials, and compact electronics etc.).

- Consumer demand
  - ICT connectivity
  - Sharing economy

- Regulations concerning
  - Emissions
  - Safety

There are several important **assumptions** as to the expected socio-economic effects of CAM:

- Significant decrease of costs for automated driving services[11], especially trucking[12];

- Significant improvements in road safety[13];

- Enabling technology for new services on demand;

- Increased connectivity in rural areas caused by cheap driverless ride-hailing services or public transport;

- Social inclusion: improved mobility for elder people, children, people with special needs[14];

- Positive environmental effects caused by a more energy-saving driving style, less congestion via optimised driving, with less accidents also less need for repair; when combined with car-sharing less parking space and

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[10] Congress 2018, p. 2.

[11] Labour costs amount to 60 % of ride-hailing services. UBS bank forecasts that automation, competition and electrification will cut the cost of ride-hailing by 70% (EC 2018, p. 1).

[12] According to Wall Street Analysts Bernstein, labour costs account for 43% of the trucking industry's cost. Provided for the higher costs of driverless lorries, cost saving of the trucking industry could still amount to 85-105 BEUR (https://www.businessinsider.de/driverless-trucks-300-billion-savings-tesla-2017-11?r=US&IR=T).

[13] 94% of road accidents are caused by human errors (Congress 2018, p. 1).

[14] See e.g. EC 2018, p. 1.

better capacity utilisation[15]; when combined with electric propulsion less air pollution and GHG emissions.

Given the crucial economic and therefore political importance of the automotive industry[16] (in the wake of the "Dieselgate"[17] scandals), it seems safe to assume that considerable economic interests are a main driver behind the recent interest in CAM. Expected revenues from CAM by 2025 for the EU automotive industry amount to 620 BEUR and for the electronics sector to 180 BEUR[18]. Spill-over effects are expected to other sectors in the value chain[19].

Most studies and papers assume that CAM will come together with increased car-sharing and 'mobility as a service' as well as electro mobility[20]. However, these three assumptions are not intrinsically linked – it is conceivable that e.g. only electro mobility or electro mobility together with CAM will become widespread and that car-sharing will remain a minor part of the market.

As to the **timeframe**, the numerous existing studies on the subject widely disagree on when Level 5 CAM systems will be introduced on the market and when they will dominate the roads. The below table gives an overview of the different forecasts.

Table 2. Overview of technology forecasts related to CAM

Institute	Aspect	By
European Commission COM (2018) 283 final	Provided the regulatory and enabling framework is in place, vehicles driving themselves under specific driving conditions.	On market by 2020 Commonplace by 2030
Boston Consulting Group	Automated vehicles should represent 20% of global vehicle sales	2025
ERTRAC	Differentiates three main markets: ▪ Passenger cars ▪ Lorries and freight vehicles	Level 4: mid to late 2020ies Level 5: after 2030

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[15] Vehicles can be in continuous use if shared and therefore less vehicles and thus less parking space is required.

[16] The car market is a growth market. In the first quarter of 2018, the car market in the EU grew by 0.7 %, in the USA by 2.0 % and in China (representing 29.5 % of the global market) by 5.6 %. World-wide growth of the industry was 2.8 % (https://www.acea.be/automobile-industry/facts-about-the-industry). The number of passenger cars in the EU-28 has seen a growth of 2.3 % between 2014 and 2015, the stock of goods vehicles grew by 2.0 % (Eurostat 2017, p. 50 and 89). See Introduction for further information on the importance of the automotive industry.

[17] See e.g. https://www.bbc.com/news/business-34324772

[18] JRC 2018.

[19] Positive effects are expected for the automotive, electronics and software, telecommunication, data services and digital media as well as the freight transport sectors; negative effects are expected for the insurance as well as maintenance and repair sectors, due to less accidents (JRC 2018, p. 6). See also EC 2018, p. 1.

[20] See e.g. EC 2018, p. 1: "*They* [driverless vehicles] *could encourage car-sharing schemes and 'mobility as a service' (i.e. selling rides, not cars). They could also accelerate vehicle electrification and electro-mobility*".

Institute	Aspect	By
	▪ Urban mobility vehicles *"In one sentence: in 2050, vehicles should be electrified, automated and shared.[21]"*	Target: 2050 exclusively CAM
Honda[22]	"Production vehicles with automated driving capabilities on highways sometime around 2020."	2020
Ford Motor Company[23]	"fully autonomous vehicle" coming in 2021	2021
Mazda Motor Corporation[24]	"Dreams to be realised until 2030"	2030
Hitachi Ltd.[25]	Autonomous car industry will be worth 50 BEUR in 2030	2030
Stanford University[26]	"In two years, we'll have 10 million self-driving cars on the road."	2020
Toyota Research Institute	"it is very likely a number of companies will within a decade have Level 4 cars operating in specific areas" "none of […] the automobile or IT industries are close to achieving true Level 5 autonomy, we are not even close."[27]	2020 - 2030

The forecasts in the various studies are best summed up in two statements cited from the literature:

■ "Automated vehicles are not yet ready to operate without human supervision[28]."

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[21] ERTRAC 2017, p. 4.

[22] Honda: http://www.hondanews.com/releases/honda-and-alphabet-inc-s-waymo-enter-discussions-on-technical-collaboration-of-fully-self-driving-automobile-technology?utm_medium=email&utm_campaign=Honda%20and%20Alphabet%20Incs%20Waymo%20Enter%20Discussions%20on%20Technical%20Collaboration%20of%20Fully%20Self-driving%20Automobile%20Technology&utm_content=Honda%20and%20Alphabet%20Incs%20Waymo%20Enter%20Discussions%20on%20Technical%20Collaboration%20of%20Fully%20Self-driving%20Automobile%20Technology+CID_792126b8903db549b4e67a4bb26d496d&utm_source=Honda%20Campaign%20Monitor&utm_term=View%20Full%20Release

[23] Ford: https://media.ford.com/content/fordmedia/fna/us/en/news/2016/08/16/ford-targets-fully-autonomous-vehicle-for-ride-sharing-in-2021.html

[24] Mazda 2016, p. 10.

[25] Hitachi 2016, p. 1.

[26] Stanford Engineering: https://engineering.stanford.edu/magazine/article/traveling-age-driverless-cars

[27] Toyota: CES 2017 Press Conference Livestream on Youtube.

[28] EC 2018, p. 2.

■ "Views differ as to how long it may take for full automation to become standard[29]."

Besides open RTDI and engineering tasks, there are important non-technological **challenges** to be solved for large-scale deployment of CAM, most notably:

■ **Interoperability** of sensors, traffic signs etc., standardisation of communication platforms – not to forget safe language recognition; this has to happen world-wide due to the globalised nature of the automotive industry;

■ Upgrading of existing road and digital **infrastructure**, future maintenance of road infrastructure;

■ Impact on **other business sectors**, be it positive (electronics industry) or negative (repair shops);

■ Impact on **mass public urban transport** that most likely will have to compete with (if not be cannibalised by) mobility services based on CAM;

■ Involvement of all **stakeholders**, including social partners, consumer representatives;

■ Impact on **employment**: positive (electronics industry), negative (lorry, taxi drivers – less so bus drivers since conductor/safety staff might still be necessary) with consequences for **education**, up-skilling and training.

■ User acceptance[30];

■ A broad set of **legal** questions[31];

■ **Ethical** questions, e.g. in case of an unavoidable crash.

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[29] Congress 2018, p. 3.
[30] 58% of European citizens declare being ready to use CAM (EC 2018, p. 1).
[31] See dedicated Chapter on Legal implications of CAM.

A key point remains in any case: there will be considerable periods when different stages of CAM will **co-exist** with conventional road mobility, i.e. vehicles driven by human beings[32]. It may be the case that a market segmentation between cars currently predominantly offered as fun and sports vehicles (that might not sell as driverless versions only) and "bread and butter" cars for driverless use prolongs the phase of mixed traffic even over the lifespan of the heritage cars. And in any case, two-wheelers, bicycles and pedestrians will remain as road users sharing traffic space with CAM[33].

Concerning **roadside infrastructure** required for CAM, current research goes towards vehicles that can use the same infrastructure as today's human drivers. However, improved road infrastructure might be required to speed up the deployment of CAM, to avoid costly technology for dealing with imperfections and to increase safety and reliability of CAM systems[34]. The illustration below gives an example of such installations, in this case for traffic lights.

Figure 1.   Example of a road-side installation
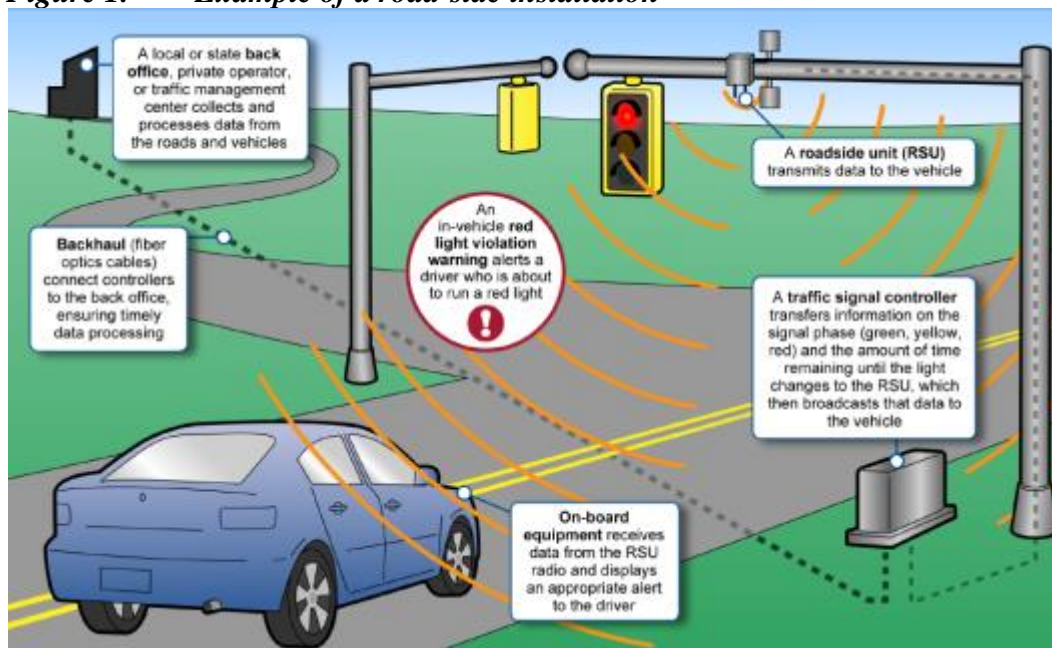
Source: *United States Government Accountability Office (GAO)[35].*

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[32] According to ACEA, the average age of passenger car in Europe is 10.7 years; however, with marked differences between individual MS: whereas cars in LU are on the average 6.2 years old, the average car in RO is 15 years old (www.autoundwirtschaft.at). According to Eurostat data, in most EU-13 and Mediterranean countries, more than 50% of the cars are more than 15 years old. With a significant share of EU passenger cars being more than 15 years old and if the trend prevails, e.g. many of the non-automated Euro 5 diesel cars that have been sold until 2015 will still be in service by 2030/2035/2040. On the other hand side, only 1.7 % of all cars sold at the moment in the EU are electrically chargeable (ACEA).

[33] However, it might be conceivable that in the future also pedestrians or bicycles become tagged and, in this way, also become participants in connected mobility systems.

[34] Greater Ann Arbor Region 2017, p. 12. The United States Department of Transport estimated investment costs of ca. EUR 45,000 per site (without recurring operations and maintenance cost) with necessary replacement every 5 to 10 years (GAO 2015, p. 40).

[35] Cited from Greater Ann Arbor Region 2017, p. 16.

In its Communication "On the road to automated mobility: An EU strategy for mobility of the future", the European Commission declares key **policy** objectives[36]:

■ "The ambition is to make Europe a world leader in the deployment of connected and automated mobility, making a step-change in Europe in bringing down the number of road fatalities, reducing harmful emissions from transport and reducing congestion."

■ "For Europe to remain competitive and foster employment, it will be essential that the key technologies, services and infrastructure are developed and produced in Europe and that the necessary regulatory framework is in place."

The EC has set up its strategy based on consultations with MS and stakeholders, mainly through the GEAR High Level Group on automotive industry which adopted recommendations in October 2017. Especially since 2016, numerous policy texts have been published by EU bodies in the subject[37]. An EU Directive on Intelligent Transport Systems is in place[38]. In addition, a considerable number of RTDI project initiatives, communication platforms, public-private partnerships have been established at European level as well as at an international level[39].

In many MS (e.g. DE FR, UK, SE, FI, AT) as well as in all overseas countries with a large automotive sector (PRC, USA, JPN, KOR), national initiatives supporting CAM testing and development have been launched[40]. It is interesting to note that among the ten EU MS with the largest share of jobs in the automotive industry[41], the EU-15 MS (DE/3rd highest share, SE/6th, FR/9th, AT/10th) all have initiatives in place, whereas the EU-13 MS (CZ/1st, SK/2nd, HU/4th, RO/7th, SI/8th) seem to be considerably less active with CAM-related research projects[42].

The below table summarises the key implications of the SAE Levels of automatisation on the main road transport markets.

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[36] EC 201, p. 2 and 5.

[37] See the section with References at the end of the Document.

[38] Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

[39] For an overview see ERTRAC 2017, p. 17-22 and 28-29.

[40] For an overview see ERTRAC 2017, p. 22-28 and 30-35.

[41] In terms of "direct automotive manufacturing employment active population ratio"; ACEA 2018, p. 16.

[42] The website https://connectedautomateddriving.eu/research/ lists 43 research projects for DE, 26 for FR, 16 for AT and 15 for SE; whereas for the EU-13 countries, the figures are between 0 (RO) and 3 (HU, SI, SK). However, test tracks are planned in CZ, SK and HU. On the issue of "extended workbenches" see e.g. de Wet.

Table 3. Modes of transport, stages of automation and key implications

| Mode | Key implications | | | | |
	Level 1	Level 2	Level 3	Level 4	Level 5
Passenger car	Existing systems	Existing systems	Driver has to take over from the machine – critical interface!	Legal implications become crucial due to the diminishing role of the driver	No driver required, people without licence can drive
On demand service	Existing systems	Existing systems	Gradual take-over of automated functions taking the needs of vulnerable users[43] into account		No driver required, cost savings
Bus (public)	Existing systems	Existing systems	See above - same as for on-demand solutions	No driver required on specific sections	No driver required, probably replaced by conductor/ security/ service staff
Lorry	Existing systems	Existing systems	Interesting for main hauls over highways. Might increase safety but significant change of job profile for truck drivers	No driver required in specific areas	No driver required, cost savings. Limited cost savings for distribution in urban areas (loading / unloading will require staffing)

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[43] Under vulnerable users we would see persons with lack of language command in written, not using advanced mobile devices etc.

2 Future challenges and opportunities for LRA in connection with CAM

LRA and their decisive role in transport policies

From today's perspective the development pathway towards CAM and its implications for LRA are linked to considerable uncertainties related to timing, scale and direction(s) of the impact of CAM. At first it is important to see that LRA have a multi-dimensional role in transport policy on their territories. LRA are:

- developing local and influencing regional and national transport policies,
- enforcing traffic rules,
- providing infrastructure,
- providing transport services,
- providing Services of General Interest (SGIs) including transport.

When looking at these roles or functions in transport policy it is useful to consider the character of policy levers thus making a distinction between incentive policies and regulatory policies; both types of levers do have significant impact for developments in transport and thus also for future CAM.

Regarding the set of **incentive policies** of LRA related to transport, the following aspects should be taken into consideration:

- Primarily, one has to concede that LRA have **limited capacities** to support RTDI in vehicle technology but quite a substantial need – in particular for major cities – to consider developments in traffic management systems.

- LRA require specific car pools which are an interesting market for automotive industries; e.g. cities that have large car parks, which are mostly utility vehicles for provision of Services of General Interest (SGIs)[44]: associations of LRA could influence technology development towards CAM for **utility vehicles** with their 'accumulated' purchasing power.

- Especially the aspect of improved **road safety** might require road design and infrastructure equipment (such as traffic lights) which is better responding to the requirements of CAM.

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[44] Many of key Services of General Interest (SGI) imply transport services such as: maintenance of almost all public utilities, waste management, healthcare and care for elderly citizens, emergency services such as police, ambulance, fire brigades.

- Support for specific modes of transport which influence the behaviour of users, e.g. **subsidies** for public transport for students, elderly citizens and other target groups.

- Parking management systems;

- **Traffic management** and user charge systems in order to steer and contain traffic flows such as city toll systems;

- Measures for the integration of multiple modes of transport into seamless **transport chains** by various means such as integrated ticketing and payment systems or privileged access etc.

In terms of **regulatory policies**, it is evident that key legal issues such as general traffic rules as well as vehicle and safety standards will be subject to national as well as EU legislation. In some key areas LRA will have a decisive role, e.g.:

- **Road infrastructure:** LRA, in particular local authorities are by far the largest operators of road networks across the EU[45], i.e. any investment required for local networks in order to safeguard interoperability for respectively safe operation of CAM will strongly affect LRA as road operators.

- **Local traffic rules:** in hands of LRA one can see local traffic and parking rules as key legislation directly impacting CAM – most probably in densely built urban areas local solutions will be supported by traffic management systems.

- **Planning** as a key lever to shape traffic development in the long run: i.e. building and zoning plans shape mobility behaviour and mobility patterns; zoning is particularly decisive if settlement structures can be covered efficiently and effectively by public mass transport; the general legislation on planning is usually part of national and/or regional legislation but the decision on concrete plans is usually a key task of local authorities throughout the EU.

- **Public service contracts** (PSC) for road- and rail-based public urban and regional transport.

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[45] A few numbers in order to briefly outline the scope : in DE the total length of road network amounts to 644,480 km; thereof 413,000 km (i.e. 64% of the network) are classified as local roads, i.e. the local authorities are in charge of operation and maintenance; for the UK the total length of the road network amounts to 397,025 km ; thereof 87.3% is managed by local authorities (cf. DoT 2018, p. 1).

As a tentative summary from the perspective of LRA the following major strengths and weaknesses as well as opportunities and threats can be identified:

Table 4. SWOT analysis of LRA regarding CAM

Strengths	Opportunities
▪ Good knowledge of local transport needs and challenges ▪ Experience with set-up and management of local/regional transport services ▪ Possibility to influence traffic patterns via e.g. building and zoning plans and traffic regulations	▪ Introduction of new mobility services on demand improving connectivity, especially in rural areas ▪ Introduction of more cost-efficient mobility services for children, elderly people, people with special needs ▪ Cost savings with municipal utility vehicles ▪ Increased road safety ▪ most probably new options to monitor and manage traffic; improved data collection as road infrastructure manager
Weaknesses	**Threats**
▪ Insufficient funds ▪ Insufficient knowledge of opportunities and threats of CAM ▪ Difficulties to monitor technology developments and develop unified policy responses owing to capacity constraints	▪ Cannibalisation of existing mass public urban transport by cheaper mobility on demand services ▪ Increased road traffic ▪ Higher cost for construction and maintenance of interoperable road infrastructure ▪ Increased liability risk as road infrastructure manager

Source: own considerations.

Spotlight on LRA as infrastructure operators

From the perspective of LRA the aspect of **infrastructure** deserves particular attention – also owing to the fact that safe road conditions will be one of the pre-conditions in order to achieve improved road safety throughout the testing phase and the stepwise introduction of CAM:

■ Adjustments of streetscape might have to be considered in order to optimise the use of automated vehicles – such as added curb space for pick-up and drop-off areas.[46]

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[46] Cf. Greater Anna Arbor Region 2017, p. 10.

- Other amendments, which are in general desirable, might become crucial in order to actually improve road safety for vulnerable road users[47] – such as lighting of pedestrian crossings, improved road marking for the demarcation of cycle pathways and improved design and maintenance of road signs.

- CAM compatible traffic management systems in areas of high traffic density, i.e. high numbers of cars, pedestrians, cyclists, scooters might impose considerable investment needs – currently based on quite uncertain assumptions; e.g. road side units, traffic signal controllers[48] or traffic management centres[49].

- With a view to the liability of road operators, the accurate and timely information about construction works, detours and dangerous road conditions[50] or any other road hazards will become increasingly important[51].

- Another aspect closely related to infrastructure is the need for highly detailed digital maps with a reasonable degree of standardisation – an important ancillary "soft" infrastructure which cannot be developed efficiently at the level of LRA; LRA will be challenged e.g. to support update when new local roads are opened in expanded settlement areas or roads are closed partly/completely for car traffic.

Diversity of LRA across the EU

When looking at the decisive role of LRA in transport policy it is important to take the diversity of LRA across the EU into account. Densely populated Member States (MS) such as the Netherlands show a high share of urban land use and urban transport is characterised by comparatively high shares of vulnerable road users – whereas in most Nordic MS and the interior of the Iberian Peninsula settlement structures are quite different. Just as the determining factors for transport, e.g. settlement structures, topography and climate, differ – so the approaches to transport policy will differ markedly.[52] These can be considered as geographical challenges which should be duly noticed when developing adequate systems and services related to CAM.

The different effects of the same CAM-based solution can be illustrated in the following example:

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[47] Pedestrians, in particular children and elderly citizens, cyclists.
[48] Devices that generate signal phase and timing messages to road side units.
[49] System that collects and processes aggregated data from vehicles and infrastructure.
[50] E.g. ice on bridges when other stretches of the road are reasonably safe and dry.
[51] Cf. Greater Anna Arbor Region, 2017, p. 11.
[52] EU 2016, p. 11.

- ■ cheap driverless micro-buses might be a beneficial development in rural areas ensuring mobility for elderly people or to run transport to school more cost-efficiently;

- ■ in dense urban areas, such vehicles might increase the traffic load in already congested areas and pose additional competition to public mass transport.

Spotlight on urban areas

The trend towards further urbanisation in the EU and enlarging suburbs around the capital cities as well as selected secondary and tertiary cities is evident. Urban agglomeration areas are and will be the key sources of transport as well as the key markets for mobility services and thus also for future CAM. It is the place where young and highly skilled people work and live, who are more likely to use the options offered by CAM. At the same time cities are the LRA which are confronted with the consequences of an aging population at a significant scale. Healthcare is one of the areas where new cost-efficient transport services on-demand might be of particular interest. Furthermore, suburbanisation will continue thus creating areas particularly interesting for other on-demand services.

These exemplary options point at the significant role of cities as test beds for CAM. In this way, the industry will be challenged to work on the acceptance of CAM and to take the cost-efficiency of traffic management and infrastructure equipment for LRA into account.

Transport policy development will also be shaped by environmental concerns: cities are challenged by the air emissions caused by transport which is one of the adverse factors lowering the quality of living. Thus, for urban car traffic the development of CAM is ultimately linked to the development of low emission vehicles. In terms of energy efficiency it is clear that urban public mass transport is by far the most environmentally-friendly mode of transport. Regulatory policies will be the key policy levers in order to ensure that CAM does not lead to increased traffic at the expense of public mass transport.

The EU's urban agenda includes 12 theme-related urban partnerships. One of the partnerships is dedicated to urban mobility – The Urban Mobility Partnership established in 2017 might consider to take CAM on its agenda in the sense of an early technology monitoring and the formulation of adequate policy responses for a smooth introduction of CAM.

Interoperability

The key question for smooth and efficient operation of CAM will most likely be the interoperability of systems which will have to be solved at European respectively global level. One of the key issues is to which extent future CAM vehicles will require specific guidance systems in order to ensure higher safety standards compared to conventional cars. If vehicle-to-infrastructure communication becomes a vital element in CAM systems, a number of questions concerning standardisation or interoperability of infrastructure equipment at European level will arise. E.g. road information systems are the fundament for many more advanced applications: since one can assume that LRA as road operators would have to provide and update the information, interoperable respectively standardised systems would be important.

At the moment, the EC has a technology-neutral approach regarding the connectivity of vehicles. There is no mandatory employment of specific technologies – however, this may become necessary in the future. It remains to be seen to what extent LRA are affected since it is not yet clear, which roadside installations will be required. It should be avoided that stranded costs for incompatible or outdated equipment have to be covered by LRA.

Further aspects include setting up guidelines for cybersecurity, which are established at EC and UN level – however, have to be implemented at a local level, too – and e.g. the fair access to repair and maintenance information for independent repairers and municipal bus depots.

Cross-border coordination and cooperation

The stepwise introduction of CAM would benefit from cross-border coordination and cooperation in several action areas which are closely related to the role of LRA as road managers and as providers of SGIs:

Table 5. Action areas for cross-border cooperation related to CAM

Action areas	Important issues	Timing
Cross-border testing	EU Member States asked the EC to develop a joint European strategy on CAM to ensure exchange on common methods for testing, evaluation, exchange of knowledge as well as lessons learned – in order to coordinate large-scale cross-border testing in specific regions. ▪ Agreements between Member States should include provisions on the involvement of LRA; feedback to LRA as road operators should be a standard element.	Short-term

Action areas	Important issues	Timing
	▪ The knowledge which is most relevant for LRA as road operators should be structured and serve as input to further research on plausible infrastructure endowments for CAM.	
Traffic management systems for cross-border conurbations	CAM-compatible traffic management systems could become shared infrastructure.[53]	Mid- to long term
CAM-operated services on demand	CAM-operated services on demand across borders might be an interesting option for cross-border conurbations but also for local authorities in rural and peripheral areas (shared operation could help to curb costs). The inherent challenges such as safe language recognition and easy ticketing and payment options might be interesting add-on elements to larger research projects in the field of CAM-operated public transport services.	Mid- to long-term

Source: own considerations.

An important enabler with a local component will be the implementation of the pan-European 5G cross-border corridors.

Conclusions related to LRA

It will be key for LRA to monitor technology developments and to raise their voice in order to shape and influence the development of adequate policy responses in relation to planning and investment. From the perspective of LRA the aspect of corresponding **requirements and developments in infrastructure** is decisive. Expanding testing on open roads is an evident requirement to develop CAM and a growing number of testing areas will increasingly call for better information of LRA by national and supranational bodies as well as from LRA to the testers on legal and regulatory provisions to ensure safety for other road users. It is obvious that unified claims and calls for unified approaches across large numbers of LRA could have significant impact in policy debates.

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[53] It is evident that the more standardised such systems would be, the easier it would be to set-up shared traffic management systems in cross-border agglomerations.

3 Funding opportunities for LRA for CAM systems and infrastructure

As the EC points out in its recently published Communication, large parts of the necessary investment for the introduction of CAM systems will be done by the private sector. Research activities as well as deployment of public roadside and digital infrastructure will profit from other funding sources[54]. At the moment EC is dealing with the update of the research and innovation map for driverless mobility. MS have started identifying a set of pan-European cross-border 5G corridors to support large-scale tests and deployment of CAM infrastructure.

■ **Horizon 2020**

For 2014-2020, a total budget of approx. MEUR 300 from the EU RTDI framework programme Horizon 2020 has been dedicated to automated vehicles – half of which was provided through calls launched in 2016-2017[55]. Dedicated calls for CAM are foreseen between 2018 and 2020 with a budget of 103 MEUR. In addition, MEUR 50 were set aside in 2018 for testing 5G connectivity to enable CAM and new mobility services. Horizon 2020 supports PPPs in innovation areas that are crucial for CAM.

The plans for *Horizon Europe* as the successor for Horizon 2020 foresee a further increase of the budget to BEUR 97.6.[56] In particular the intended **open innovation pillar** as well as the global challenges pillar strive for policy goals which leave ample room for funding of CAM development: *the open innovation pillar aims to make Europe a front-runner in market-creating innovation;* the global challenges pillar includes among others a focus on clean mobility.

Given the importance of LRA in the field of mobility policies it is utmost advisable that governance of Europe's largest funding facility for RDTI takes the requirements of LRA better into account,[57] i.e. as participants and beneficiaries (e.g. in their function as managers of test beds with the later objective to develop cost-efficient infrastructure equipment) and as facilitators.

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[54] EC 2018, p. 6-8.

[55] An overview of Horizon 2020-funded projects related to CAM can be found under ERTRAC 2018, p. 16 and 51-54.

[56] EC 2018a; almost 98 BEUR would represent a significant increase compared to about 80 BEUR for the 7-years period 2014-2020.

[57] Cf. CoR, 2017, p. 1.

■ **Digital Europe programme** (proposed for the forthcoming MFF)

The digital Europe could have an important ancillary function for the development of CAM since it aims *"to boost frontline investment in high-performance computing, artificial intelligence and cybersecurity[58]"*. It is an unprecedented initiative; the proposed budget amounts to BEUR 9.2.

■ **Connecting Europe Facility** (for road and digital infrastructure)

Funds from the Connecting Europe Facility destined for the digitisation of road infrastructure provided a basis for automation (MEUR 443 triggering MEUR 1,173 of total investments). Up to MEUR 450 are made available to support digitisation in transport. It is key for CEF – which will most likely be continued beyond 2020 – to expand its focus on the compatibility of digital systems across borders.

■ **European Structural and Investment Funds (ESIF)**

Ideally speaking ESIF – in particular the European Fund for Regional Development – could be used to translate frontrunning research and innovation projects could into targeted regional implementation on site such as the adjustment of technologies to the conditions of a particular LRA. The current Thematic Objectives for ERDF point at ample options to support such projects.

The draft regulations for the ESIF in the period post 2020 do also foresee a major policy objective on research and innovation (Smarter Europe) which will be a crucial pillar in the mainstream programmes of most of the European regions. As a side-line to mainstream programmes funded from ERDF the European territorial Cooperation (ETC) or Interreg programmes might support targeted know-how transfer (e.g. between cities) or cross-border piloting in conurbations exceeding national borders either in cross-border or transnational programmes.

■ **Funding know-how transfer, knowledge management and coordination**

For the smooth introduction of CAM funding for targeted know-how-transfer, knowledge management and coordination will be crucial. One of the examples for knowledge platforms targeting the information needs of LRA could be the Urban Mobility Partnership in the framework of the European Urban Agenda.[59] Also the GEAR 2030 initiative should seek to develop and support policy options in this field.

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[58] EC 2018a.
[59] Which is likely to be continued beyond 2020 in the framework of the intended European Urban Initiative.

◼ Public-private partnerships

On the one hand, the introduction of CAM will largely rely on input and investment from the private sector – on the other hand, LRA play a crucial role in the actual design and deployment of the systems.

Toll-based systems (motorways, but also e.g. city centres, mountain roads, panorama roads) have potential for PPP, covering roadside installations required for CAM. The Hungarian motorway M5 is a well-known example of opportunities and challenges of toll-based PPP systems, as well as the German A-model.

The generation of large amounts of valuable data might make CAM systems interesting for private sector participation via PPPs. The U.S. Department of Transportation and Sidewalk Labs, a subsidiary of Google's parent company Alphabet, set up the PPP "Flow" to improve the compatibility of existing transport infrastructure in major cities with CAM.[60]

A US study by Public Sector Consultants points out the potential for PPPs between transport authorities and ride-hailing services to improve connectivity since research shows that users of ride-hailing and car-sharing services are more likely to use public transport[61]. SMRT, the public transport operator of Singapore, acquired a 20% share in the Dutch provider of autonomous vehicle systems "2getthere".[62]

The implementation of well-functioning PPP structures requires specialist skills that are not necessarily available in all LRA. LRA need to be able to adequately assess the risks and set up suitable structures.

◼ Public service contracts

For public transport systems, the main instrument for LRA will be public service contracts according to Regulation (EC) 1370/2007 with the respective national funding of compensation payments.

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[60] Flow will aggregate (process and analyse) anonymised data from smartphones, traffic sensors, etc. to provide municipalities with real-time information on traffic patterns, available parking space as well as air and noise pollution. At a later stage, Flow will also create mobile applications.
[61] Greater Ann Arbor Region 2017, p. 9.
[62] https://www.waterstreetpartners.net/blog/autonomous-vehicle-partnerships-an-update

4 Legal implications of CAM for LRA

When considering the digital revolution transforming services, industrial production as well as behaviour patterns – the development of CAM stands out owing to the fact that any automated driving technology active in a road vehicle poses an immediate risk to other road users in case of failure.

One also has to see that legislation tends to lag behind technology developments: it is hard to put exact dates to envisaged milestones in the development process; ambitious technological goals might not be met completely and alternative developments in other related fields might require changes to the initial schedule.

Policy-makers face the challenges to set-up regulatory frameworks which:

■ follow technology developments quite closely – belated attempts to regulate CAM bear serious risks related to safety and public acceptance and might hinder technological progress;

■ take the particular implications of the operation of automated and non-automated vehicles into account;

■ respect environmental standards.

Several layers of legislation are decisive for transport policy which is understood mostly as regulatory policy.

Table 6. Aspects in legislation related to transport policy and emerging CAM

Issue	Level	Implications for CAM
Road traffic act	national	Stepwise integration of CAM into the road traffic act; correct use of assistance systems in Levels 1 to 3 In Levels 4 and 5 the driver no longer exists – thus clarification who is in charge to ensure that vehicle is operating safely.
Enforcement of traffic rules	national	In theory Levels 4 and 5 would allow for in-built enforcement.
Driving licence	EU national	Stepwise integration of CAM into driving licence education in stages 1 to 3.
Other legal matters	national	At those stages where no driver would be required new safety concerns might come up e.g. children using services who would not be allowed to do so; errors in language recognition in case of on-demand services leading to legal disputes; wrong reaction patterns in case of dangerous situations e.g. in deprived urban neighbourhoods.

Issue	Level	Implications for CAM
Road maintenance and operation	UN EU national regional local	Traffic signs and road markings will eventually need to comply with strict international standards (causing liability risks in case of non-compliance).

Electronic car – infrastructure communication: relates to questions of data privacy (use of data generated for public and commercial services) and cybersecurity (liability risks). |
| Environmental standards for vehicles | EU national | The development of energy-efficient alternative drive (engine) technologies is not necessarily connected to development of automated systems but current car manufacturers are leading in development – thus disruptive developments in engine technologies might be delayed. |
| Environmental regulations | national regional local | One can expect that urban mobility will be shaped increasingly by regulations stemming from environmental aspects: In order to decrease urban air pollution regulations e.g. toll systems driving bans for certain vehicles will become more widespread in the centres of growing agglomeration areas; CAM is thus challenged by the parallel development of alternative drive technologies. |
| Tax and insurance | national | The regulations on taxes and insurances are decisive for cost of operation thus also for vehicle ownership and mobility patterns.

CAM means to consider the aspect of liability with an increasing role of the system producer from Levels 3 to 5.

Taxation on cars tends to favour new cars and alternative drive technology (currently e-cars) in many countries in order to foster quicker turnover in the car stock; thus one can assume that tax incentives for the purchase of automated state-of-the-art vehicles might be introduced. |
| Business regulations | national | New services based on CAM might challenge existing business regulations, like Uber or Airbnb already do. |
| Ethics | EU national | At Levels 4 and especially 5 the machine takes over decisions of actions in a real-world environment with potentially far-reaching consequences (e.g. in cases of an unavoidable crash). Therefore, ethical questions arise that have to be provided for in the behaviour patterns of the machine. |

Source: own considerations.

The staggered system introduction adds another dimension:

■ Current legislation deals with test configurations.
■ With a wide-spread availability of Level 3 systems[63], a focus will probably have to be on the precarious and accident-prone driver/machine-interface.
■ Wide-scale introduction of fully automated Level 5 systems will trigger far-reaching changes in the legal framework.

LRA will be affected in **administrative issues**, e.g. concerning driver's licences for CAM, changed traffic rules with less infractions of the rules or challenges to existing business regulations by new services (comparable to the current discussions around Uber).

CAM introduces new **liability** risks for LRA such as:

■ Infrastructure managers of local roads;
■ Providers of urban and regional transport services run by CAM;

The risks are mainly connected with:

■ Accidents,
■ Data protection;

With Level 4 and 5 systems, humans will not be responsible for driving the vehicle anymore. Therefore, liability in case of **accidents** will have to be taken over by other players in the system like car manufacturers, software developers, traffic control systems, car owners (like municipal transport companies) or road infrastructure managers; the latter in case of accidents caused by defective infrastructure (e.g. unreadable/wrong road signs or road markings). At the moment, the liability issues connected with Level 5 CAM are under discussion and unsolved.

Data protection mainly concerns the data exchange between the car and its surroundings. The communication can take place with road infrastructure, traffic control systems, other cars and road users, the car manufacturer, public authorities etc. Three main aspects arise:

■ Cybersecurity,
■ Data privacy,
■ Data Access;

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[63] De facto Level 3 as brief technical lable tends to diminish the fact that this is the critical development stage where the decision on reactions and commands inherent to the driver/vehicle interface are decisive.

Concerning **cybersecurity**, CAM provides many potential entrance points for hackers or malware[64]. This holds true for the car-infrastructure communication, too. Especially considering the wave of car-based terrorist attacks in the past years, there is a considerable security risk and therewith liability risk that might also hit the infrastructure manager (LRA). In any case, costs for cybersecurity measures will arise[65].

Data privacy concerns access and protection of data gathered from publicly accessible CAM systems and infrastructure. On the one hand, there is considerable business potential as well as information interest of public bodies requiring access to data generated by CAM. On the other hand, data privacy requirements like user consent to data sharing have to be complied with[66]. When the introduction of CAM is imminent, it is worthwhile considering setting up guidelines or an information point at EU level supporting LRA on the issue.

For the proper functioning of CAM systems, **data access** of road infrastructure managers to required data gathered by other players (and vice versa) has to be secured, an important issue for LRA running traffic control and management systems. The issue of data access is also crucial for a level business playing field and fair competition, e.g. for independent repair shops. Legal measures therefore have to balance the requirements of fair competition, requirements of public bodies and protection of personal data[67].

If the introduction of CAM requires increased **standardisation and interoperability** of road infrastructure, e.g. traffic signs, road markings, traffic control systems, potentially high costs for upgrading of local and regional road infrastructure according to the new standards will come up.

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[64] For a quick overview see Congress 2018, p. 9.
[65] See EC 2018, p. 12 for details on measures taken by EC and UN with respect to cybersecurity.
[66] EC 2018, p. 12.
[67] The EC plans a delegated act under the Intelligent Transport Systems Directive specifying access to data generated by vehicles for public authorities (EC 2018, p. 13).

5 Conclusions

Disruptive technologies pose a plethora of questions in the inception phase and in the end many developments happen to be rather unexpected thus necessitating significant legal adjustment at later stages.[68] As the EC pointed out in its recent Communication, a flexible policy and legislative approach will be necessary, continuously monitoring and taking into account technical development and field test results.

The development pathway towards CAM in the EU will be shaped by technology development as well as regulatory policies which will have to consider the following aspects:[69]

- **Economic competitiveness** (which from a European perspective relies to a significant extent on technical harmonisation at a global scale).

- **Environmental aspects**: the trends towards urbanisation across Europe as well as the global race for primary energy sources puts a huge question mark to the prolongation of the current developments in transport.

- **Road safety** as one of the likely beneficial effects of CAM; but it will require flanking measures which might impose considerable investment needs for LRA.

- **Interoperability** of the systems and comparable safety standards which is likely to pose considerable challenges across Europe when it comes to traffic management systems.

Even if the roadmap for widespread introduction of CAM systems is difficult to foresee and a long period of co-existence of automated and non-automated vehicles is probable, it is highly likely that such systems will be deployed and will have considerable impact on LRA.

Since CAM is labelled as transformative technology continuous **monitoring of technology developments** is recommended. From the perspective of LRA the aspect of corresponding **requirements and developments in infrastructure** is decisive. Expanding testing on open roads is an evident requirement to develop CAM and a growing number of testing areas will increasingly call for better information of LRA on legal and regulatory provisions to ensure safety for other road users. The intent to set-up a focal point as indicated by the High Level

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[68] Cf. the General Data Protection Regulation (GDPR) as a late legislative answer to a phenomenon with an enormous economic and ethical dimension.
[69] Inspired by GEAR 2017, p. 3

Group (HLG) GEAR 2030 would provide the opportunity to raise the awareness among LRA and to consider their specific interests. As the HLG recommends that *"the adaptation of vehicles and traffic rules should follow a coherent path"*[70] it points to the need for coordinated policy development. In order to provide for **information** requirements of LRA concerning CAM, guidelines or a system of info points at national or EU level could be an option.

LRA should bring in their point of view in **consultations** at national or EU level on future policy and legal steps concerning CAM since the new systems will have considerable impact at a local and regional level.

LRA as (collectively) largest road infrastructure managers play a key role in the **implementation** of CAM systems. LRA will also be decisive for the **acceptance** of CAM systems: safe and optimised road infrastructure will improve safe operation of CAM as a major precondition for the acceptance in the inception phase but also many of the current test runs are public transport services of minibuses.

LRA face additional **funding** requirements, mainly for upgrade and maintenance of road and digital infrastructure. CAM vehicles for public transport will probably be more expensive than conventional vehicles; however, this should be offset by lower costs of operation. Additional liability risks might have to be catered for, leading to additional **costs**.

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[70] Cf. GEAR 2017, p. 43.

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