MAVEN

Managing Automated Vehicles Enhances Network

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White Paper - Management of connected automated vehicles in a smart city environment

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1. Introduction

This white paper explores the intersection between 'Smart Cities' and 'Smart Mobility'. While it looks at the wider technological (and specifically mobility) innovations, it is written with a with particular focus on the EU funded MAVEN (Managing Automated Vehicles Enhances Network) project and the management of connected automated vehicles within these Smart Cities.

The white paper is a non-technical document (which can be read alongside the detailed MAVEN Transition Roadmap) and is aimed at those who require an overview of the potential impact on the city scape which technological innovation, and specifically Connected Automated Vehicles (CAVs), will induce. The paper is subdivided into 3 main sections: cities and smart, questioning what needs to happen to enable CAV adoption and managing CAV's to achieve this 'smart' future.

The MAVEN project was launched on 1st September 2016 and is a 3-year project, under the Horizon 2020 Research and Innovation Framework Programme of the European Commission (Grant Agreement No. 690727) and has nine partners.

The project aims to provide solutions for managing CAVs in an urban environment (with signalised intersections and normal, non-segregated, traffic conditions). Algorithms have been developed for organising the flow of infrastructure-assisted automated vehicles and structuring the negotiation processes between vehicles and the infrastructure. Platooning is an evident example of a technology in this domain.

Figure 1: MAVEN test vehicles at a connected signalised intersection in Braunschweig

The MAVEN approach substantially contributes to increasing traffic efficiency, improving utilisation of infrastructure capacity, and (by extension) reducing emissions. The MAVEN project has built a prototype system that is used both for field tests and for extensive modelling for impact assessment.

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Furthermore, the project contributes to the development of enabling technologies, such as telecommunication standards and high-precision maps proposals. MAVEN:

- enables smoother journeys through junctions through automated speed and lane advice;
- shares collective knowledge at intersections and beyond through V2X communications;
- reduces energy usage through dynamic platooning and optimising junction throughput, and
- sets out an approach that works for OEMs, integrators and cities.

2. Cities and ‘Smart’

2.1 A look back

Bumper to bumper in a traffic jam or crammed into the train. Throughout the world thousands of people travel from home to work every day. Commuting became a culture in itself. The commuter does not exist that long, not even a century yet, but we seem to find it normal that people flock together every day in busses, trains, metro’s cars round and about the same time in the morning and evening. It is a peculiar fact that living at an appropriate distance from work became a luxury and now leads to major problems.

It is well documented by the United Nations that 70% of the world's population is projected to live in cities by 2050. This introduces challenges for transport such as: increased pressure on resources, increased demand for services, increased need for sustainability and resilience, increased need for accessibility and increased pressure on space.

2.2 A look ahead

The future has begun. Car showrooms no longer exist. Europe has Mobility as a Service (MaaS) completely embraced; your travel options - multi modal, (active, public or private) and their timings, costs and payment systems are available at the touch of a button on a single App. We are completely unburdened in the area of mobility. Owning a car is no longer necessary. It is strange to think that we once had two of our own cars at the door.

The street scene is filled with futuristic people movers. A trip from A to B is requested: "I would like to go from Greenwich to Canterbury". You will then be picked up by a, possibly, self-driving vehicle within an agreed time frame and you will be on your way to your destination. You chose your travel options (pick at home, at a hub, at the street corner, a shared or a private journey), on a preference platform built into the mobility App. Conventional vehicles are still driving around, but these have not been produced for years and are therefore rapidly disappearing from the street scene.

The traditional car manufacturers still exist, but only produce vehicles for service providers such as Uber, Lyft, Waymo and Apple. Every service provider offers three comfort classes: economy, standard, luxury or special purpose vehicles (for example a transport van or special accessibility for wheelchairs). The user can therefore indicate with which class of vehicle he / she wants to make a ride: "I would like a luxury ride from Russelsheim to Amersfoort".

New vehicles are only powered electrically, green of course, or by hydrogen. In addition, all vehicles driving around (both conventional and self-driving) are mandated by legislation to be cooperative. Vehicle to Vehicle (V2V) Vehicle to Infrastructure (V2I) and vehicle to Everything (V2X) communications are commonplace.

The street scene has become a shared space. However, there are several kiss - and - ride places where vehicles can stop to get passengers on and off. If a vehicle has to be parked for a longer

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period of time, this will be done on large parking lots outside the city or town centre, but thanks to mobility as a service, vehicles are actually on the road 90 percent of the time.

2.3 Social geographical developments

The socio-demographic developments of recent decades that have led to a stable traffic and transport demand forecast for the next 10 to 15 years. However, within that there is a changing age profile with retired people becoming a much larger segment of the population, and clear behavioural change from ownership to user-ship. There is already a clear trend to be discovered in the way we deal with mobility and transport. Because of the increase of the mobility from the 1950s to the 90s, we saw the small grocer, baker and butcher around the corner disappearing and large chain stores and 'out of town' shopping centres getting more dominant. Now we see a new change in distribution of goods due to the upswing of online shopping but also a tendency to visit the specialist in the neighbourhood (LP/vinyl store, specialist and artisan producers) again. This results, as seen through our future lens, not directly in a reduction in mobility demand but may be a harbinger of a new development, Mobility as a Service (MaaS).

Late last century, much attention and effort was put into carpooling. This has not really been widely adopted for all sorts of practical and social reasons. The number of passengers per car has even fallen by 15 percent in recent years in the Netherlands. Technological advance gives the opportunity to re-examine the drivers required to facilitate ride share in CAVs and address the concerns of passengers who generally are keen to adopt 'on demand' services. Innovate UK funded projects such as MERGEGreenwich (a 1-year CAV Ride Share simulation completed in 2018) and Endeavour (a current 3 year 10 CAV vehicle ride share pilot), also in Greenwich, are looking to examine this in detail.

Currently many 'commuter families' have a second private vehicle in addition to a primary, possibly company or leased, car. These commuters may be the first target that we, also through the employer, are able to achieve engagement with for Mobility as a Service. Instead of going to work with a family lease car you order a car to pick you up and drop you off at work or your favourite public transportation hub and vice versa for the days when you need to get your shuttle. You request a "lock" and with an agreed time window you are picked up by a moving workplace. So, work starts in the car. During low demand periods the vehicle is optimised to be used as a goods distribution vehicle and then picks you up again for the journey home.

2.4 Towards 'smart' travel

The 'smart' city is designed to help mitigate the challenges in it. Smart cities will:

- minimise the use of resources and space through using better construction methods and materials;
- minimise the need for powered vehicle-based journeys through better design that both reduces the need to travel by facilitating remote working and by infrastructure which prioritises walking and cycling;
- me underpinned with robust connectivity;
- me well instrumented to allow for more optimal service delivery and maintenance, and
- me accessible such that when people do need to travel it is quick, clean and efficient.

CAVs will have an impact on many aspects of daily life, such as accessibility of services and locations, road safety, environment and spatial planning, congestion and economic growth. Therefore, local authorities will need to take into account vehicle automation in their policy making and longer-term strategic planning. MAVEN can make a valuable contribution to this exercise in

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terms of traffic management, including helping to understand the expected change to the role and responsibility of the traffic manager.

When looking to the medium and long term policy and scheme development some areas of consideration for both the Traffic Manager and strategic planners are:

- The move away from ownership to user-ship and from the car and private transport, towards MaaS;
- the role of CAVs in the MaaS mix;
- the importance and impact of ‘transition’ - a mixed fleet of automated and non-automated vehicles and timescales, and
- better use of space with potentially fewer vehicles.

2.5 Who’s managing the traffic?

From an organisational perspective, the traffic manager will still be needed despite the fact that CAVs may increasingly manage themselves as a system. There is general agreement that traffic management will become more strategic in the future, where policy goals will need to be translated into operational rules, meaning that while more operational decisions will be made by systems, these will be guided by policy. This does not mean that traffic management will become simpler, nor that there will be fewer interventions. communication between the traffic manager and the vehicle is viewed positively by some cities, such as giving directions, vehicle routing and speed control at vehicle level (e.g. Intelligent Speed Adaptation) and traffic distribution at system level. How such communication is implemented would need to be determined through common specifications among the vehicle manufacturers/OEMs, traffic managers and related industry players.

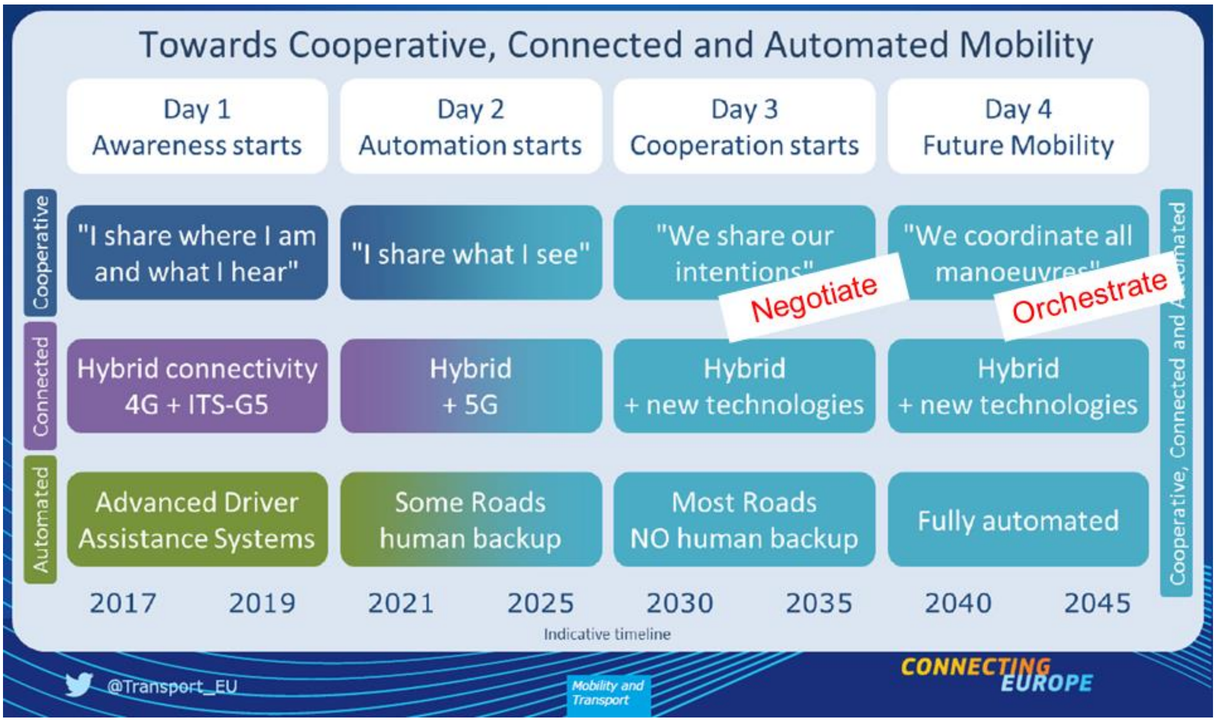

Figure 2: path towards cooperative, connected and automated mobility as presented by the European Commission, DG Move.

The coming years will see growth and investment in the deployment of Cooperative Intelligent Transport Systems (C-ITS) at both vehicles and infrastructure side, which combined with intelligent

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traffic management and control applications, will enable the road infrastructure to monitor, support and if possible or needed *orchestrate* vehicle movements. Notably, *connected driving* itself does not necessarily imply *cooperative driving*. Single traffic participants can theoretically use the additional information for their own individual advantage at the cost of others. Similarly, *automated driving* does not intrinsically cause improved traffic. If everybody decides on his own without a *cooperative coordination* with other traffic participants, then the benefits of connected and co-operative vehicle movement will not be achieved. *Automated driving* can lead to significant improvements in traffic, because optimal *cooperative behaviour* (and legal compliance) can be implemented for robots much more easily than for human beings. Robots can be programmed to comply accurately with their instructions, more than humans are capable of follow traffic management advices (unless these are autonomous robots which at some future point 'decide' to do differently).

3. What needs to happen to enable CAV adoption

3.1 The good and the bad side of automated driving

A critical question is whether CAVs increase or reduce total vehicle travel and associated external costs. To a great extent this will be a policy driven answer. By increasing travel convenience and comfort, and allowing vehicle travel by non-drivers, they could increase total vehicle mileage, but potentially in a reduced number of vehicles and they may also facilitate vehicle sharing, which allows households to reduce vehicle ownership and therefore total driving. An overview of factors that may add or mitigate congestion for fully automated vehicles is shown in the table below.

Factors that may add to congestion	**Factors that may mitigate congestion**
Individually owned AVs travelling unoccupied on return trips or while "parked" on the move; Increased demand for car use arising from those unable, or choosing not, to drive; Increased demand arising from the relaxation of the time constraint on daily travel if work can be carried out on the move, and Increased demand for lower-cost robotic taxis by former users of public transport.	Policy, technological and financial incentives and solutions to 'manage' dead running (trips between passenger carrying journeys); Scope for optimising highway used by reduced headway and lane widths on dedicated highway lanes; A reduction in city kerbside parking; Incorporation of CAV as part of the public transport offer, including shared use of robotic taxis, and Less private car ownership.

Table 1: potential impact of automated driving on congestion

Some cities are questioning the need to include CAVs in transport plans and strategies because they are 'just a vehicle technology' and the focus of plans should always be on the human. A CAV is not a separate mode, rather automation will enable new functionalities in existing modes.

Other cities see CAVs as a threat rather than an opportunity. For instance, there is a fear that transportation network companies will dominate the roads, leading to negative effects in terms of

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liveable cities' impacting on modal split, kilometres driven, congestion and less active travel (walking and cycling).

The third scenario is cities who are accepting that automation and connectivity will become part of the future mobility offer and are already looking to lock in the potential benefits, by incorporating the technology in long term plan to avoid a replication of monocentric and car focused city development of the last century.

3.2 Vehicle capabilities

One common desire across all stakeholders is to exploit the full benefits of connected and automated driving, in terms of safety, efficiency and the impact on the environment. An important aspect to consider to unlock these expected benefits, and what determines when they become available, is the operational design domain (ODD).

ODD is a description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (including weather, daytime/night-time), prevailing traffic laws and regulations, and other domain constraints[1]. Any automation use case of level 1-4 is usable only in its specific ODD, thereby an ODD can be very limiting, for instance a segregated road or a single fixed route on low-speed public streets.

The attributes of the ODD are directly connected to the way the automated driving system works and the interaction with its environment. An important aspect to realise about the ODD is that there is not one stakeholder who can affect all specific conditions, let alone control them. A vehicle manufacturer cannot guarantee that their level 4 vehicle can always drive in L4 mode, this may be limited to when the vehicle is inside its specific ODD. Similarly, a road operator would not be able to offer a road on which a L4 vehicle can be guaranteed to drive in L4 mode because of factors outside their control. For example, adverse weather conditions may prevent that. However, a mutual goal amongst stakeholders could be to 'manage' the ODD, making it as uninterrupted, stable and predictable as possible, in order to allow as much automated driving as possible thus maximising the potential benefits that are associated with it. Some of the aforementioned actions and recommendations contribute to this, although the topic of ODD and especially the factors affecting it is relatively new.

3.3 Preparing our roads

Given the diversity of cities across Europe, it is not surprising that there are very different approaches regarding CAVs. Some cities consider the role and potential impact of CAVs in their transport strategies, meaning that they are aware of the potential positive and negative impacts of CAVs and they understand the need to ensure that CAV deployment aligns with mobility goals. Some cities are looking at the impact of CAVs on wider spatial strategy. Most others are doing very little, if anything at all.

So how can public authorities prepare for automated driving? What can they do to facilitate, anticipate and/or regulate automated driving? Various initiatives have been trying to identify and structure possible actions that cities can take to progressively introduce automated driving. For example, the H2020 CoEXist project (www.h2020-coexist.eu) has proposed a CAV-ready framework for cities, which proposes actions that cities can take to progressively introduce CAVs into their policy and planning processes.

[1] *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. 2018. SAE International (Society of Automotive Engineers), On-Road Automated Driving (ORAD) committee, J3016_201609. Available from https://doi.org/10.4271/J3016_201806*

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Three phases have been identified:

- Becoming CAV aware;
- planning for automation (including defining measures), and
- implementation of measures.

A range of actions are proposed according to the three phases and considering different mobility aspects: policy, planning, infrastructure, capacity building and traffic management.

In addition, the H2020 INFRAMIX project (www.inframix.eu) has developed Infrastructure Support levels for Automated Driving (ISAD) to classify and harmonize the capabilities of a road infrastructure to support and guide CAVs . It is a relatively simple classification scheme, similar to SAE levels for the CAV capabilities. What is particular here is the interplay between the ODD, the ISAD and the three readiness-phases, which include policy making and regulation. Clearly they are related, but not interchangeable, hence collaboration and cooperation between all (inter)national parties involved in automated driving should be stimulated and coordinated. Involved parties are for example different sectors in industry, utilities, infrastructure providers, academia and public authorities.

In fact, collaboration and cooperation is one of the 7 main themes of a CAV actions and recommendations inventory, which is based on a review of a wide variety of roadmaps and action plans that aim at bringing automated driving to the roads[2]. These 7 themes are:

(1) Availability of traffic and infrastructure data;
(2) physical infrastructure requirements;
(3) traffic management and control;
(4) collaboration and cooperation;
(5) legislation and regulation;
(6) standardisation, and
(7) certification and verification.

They include both fairly basic and more advanced actions that will help public authorities to migrate from current state-of-the-art to a much richer ecosystem, for example allowing them to:

- Provide open and consistent access to real-time traffic and infrastructure data of required quality (accurate, timely) as defined by a guideline. Traffic and infrastructure data includes: traffic flows (actual & predicted), road conditions, speed limits, dynamic geometric/spatial (map) data, traffic signals, roadworks, weather, incidents and events.

- Define and/or update guidelines to ensure and maintain good state of physical infrastructure, e.g. visibility, consistency and condition of road markings, traffic signs, signals, also in adverse weather conditions.

- Develop new guidelines and practices for (distributed) traffic management and traffic control, which stimulates the interaction of in-vehicle systems at different levels of the driving tasks such as navigation and vehicle guidance, e.g. as part of scheduling algorithms for adaptive traffic light control.

[2] *CARTRE (Coordination of Automated Road Transport Deployment for Europe), D2.2: Overview and analysis of ART stakeholder groups and initiatives. Available from https://connectedautomateddriving.eu/about-us/cartre/, 2018 [Accessed April 2019].*

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- Stimulate and coordinate (inter)national collaboration and cooperation between all parties involved in automated driving. Involved parties are e.g. different sectors in industry, utilities, infrastructure providers, academia, public authorities.

- Consider different ways to regulate. For example, consider low cost approaches such as collaborative agreements or self-regulation before pursuing formal regulation or adopt best practice approaches to ensure regulation is cost efficient, transparent, proportionate to the risk, fit for purpose and done in consultation with affected stakeholders. This includes adopting relevant international or regional standards, unless there is a compelling reason for a unique requirement.

- Consider homogeneous physical design, efficiency, easy maintenance, requirements for responding to temporary speed zones, traffic controls, all likely road conditions, all likely environmental conditions and interaction with vulnerable road users, trains and light rail.

- Set up a framework for certification and verification of CAVs. Make sure the procedures are flexible to ensure they are forward-looking and responding to necessary adjustments, improvements, or changes.

Where to start?

When aggregating the aforementioned frameworks and inventories, and trying to derive a common view on what needs to happen to enable CAV adoption in cities, 6 steps can be distinguished.

1. Awareness: understand need, urgency and system functionality;
2. policy & regulation: form an opinion, assess strategic plans and define a course;
3. digital data: start providing open traffic & infrastructure related data;
4. traffic management: develop and implement new measures for vehicle guidance;
5. infrastructure: implement relevant basic infrastructure for basic services, and
6. infrastructure: implement additional advanced infrastructure for cooperative services.

As many (MAVEN) use cases are either fully vehicle-based or have a large vehicle-component, public authorities and infrastructure technology have limited influence. Nonetheless, for the example of signalised intersections, the concrete outcome of the above actions could be: digital infrastructure provides signal phase and timing and topology data; roadside sensors, communication technologies and computational resources are installed, and UTC systems are upgraded with sophisticated I2V (Infrastructure to Vehicle) algorithms.

In more general terms, to facilitate, anticipate and/or regulate automated driving, the priority for authorities might be derived from three success criteria that can characterise the introduction and deployment of automated driving: Able, Allow and Accept. Able refers to the capabilities of the vehicle given the road type, certain traffic and situational conditions, and includes the state of and functionalities provided by physical and digital infrastructure. Allow concerns regulation that prescribes where and what level of automated driving is allowed. Finally, Accept is about adoption and usage of automated driving by citizens, vehicle drivers and other road users.

Although, all three A’s are relevant and necessary on their own, they are also strongly related. For example, a system that is not or insufficiently Able or Allowed, will not be Accepted. Moreover, a system that is Able but not Allowed or Allowed but not Able, will probably never go in production for usage on public roads.

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4. Managing CAVs to achieve this ‘smart’ future

4.1 A broader perspective

The main purpose of urban traffic management is to optimise the flow of people and goods on roads, using different traffic signal configurations to maximise (or throttle) vehicle throughput at signalised intersections and influence driver behaviour by providing information such as travel times, route guidance, roadworks/congestion warnings or special events. Such optimisation must increasingly align with a range of other transport (and wider city) policies, such as emissions reduction, safety of all road users (especially vulnerable road users), economic regeneration and social cohesion.

Furthermore, a combination of market developments and new internal policies means the traffic manager is no longer alone in managing the roads and guiding vehicles. For instance, growth in in-vehicle navigation systems has meant that drivers are suggested the route that is best suited to their needs independently of the traffic manager’s preferences. The move to making public data open, including transport data, is accelerating this trend as more and more third-party service providers appear on the market and the role of the city authority as traffic and travel information service provider diminishes.

Alternatively, the management of CAVs may be taken to a whole different level. One where a traffic manager has close to full control over the distribution, movement and driving behaviour of automated vehicle fleets, in close collaboration with fleet operators, service providers and local authorities. Different approaches and priorities can be applied for automated and non-CAVs, vehicle platoons and dispersed traffic, manned and unmanned (logistics) vehicles, high-occupancy vehicles and low-occupancy vehicles, etc.

In this way, vehicle fleets like parcel delivery, goods delivery, waste collection, city maintenance and cleaning, on-demand public transport and others can be actively facilitated and regulated by network managing agents. This may include coordinated balancing of traffic volumes on different parts of the network, curb-side management to meet the increased demand for loading/off-loading bays, handling priorities at signalised intersections, speed management and harmonisation along arterials, etc.

On a slightly longer-term spatial strategy, cities need to consider the impact of CAVs. The move from ownership to usership could see parking spaces transferred to pick up/drop off or loading/off-loading bays, the road design may change with lanes for automated and optimised travel only and conventional traffic might be banned from certain areas completely. With this scenario, we also see the development of smart hubs and interchanges to mass transit facilitating urban travel demands.

5. Gap analysis and the road ahead

The MAVEN project has carried out 3 case studies in European cities, Greenwich (London, UK), Helmond in the Netherlands and Braunschweig in Germany, to understand their awareness and understanding of CAVs and Vehicle to Infrastructure technologies and how they could transform mobility within cities. As part of considering a transition roadmap for cities to enable them to prepare for an automated vehicle future, it is important to understand where existing cities and authorities are in terms of awareness, readiness and implementation.

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Figure 3: MAVEN test vehicles at connected signalised intersection in Braunschweig

The MAVEN project has leveraged the work of the CoEXist project, which was mentioned earlier. Their proposed framework consists of three phases (awareness, planning and implementation of automation) and six mobility aspects (policy, planning, infrastructure, capacity building and traffic management). The CoEXist framework of city readiness, which has been used to assess the three cities awareness, readiness and implementation of automation ready measures. Each city has been graded in each category on a 3-point scale from, no progress through partial progress to ready for each stage, for full results, see the MAVEN Transition Roadmap[3].

Based on the three case studies in the Transition Roadmap, it is clear that these cities are making progress in terms of their awareness of CAVs and MaaS and the traffic management implications of these paradigm shifts. It is also clear that other cities will be partially progressed in each of these categories and other cities may be equally progressed or even more progressed in certain areas. The purpose of this exercise is not to compare cities relative progress against each other, but rather to validate the need for a transition roadmap for cities to achieve CAV and MAVEN readiness.

For cities to adopt MAVEN style approaches it is clear that there will need to be investment in each of the areas identified within the CoEXist work. We can summarise this as follows:

- Policy - Cities are variably aware of the need to build knowledge around CAVs and MaaS, particularly from a policy perspective. If cities are to avoid being left behind as the market transitions to CAVs and MaaS, it is imperative that cities and policy makers understand what these technologies could enable and how they might influence future lifestyles and behaviours. CAVs present significant opportunities to reduce private car ownership and single occupancy journeys, which would have clear benefits to cities in terms of reduced congestion, improved air quality and a generally improved public realm. This is developed further in the MAVEN Transition Roadmap

[3] *Boschetti, F., et al. 'Deliverable D8.4 Transition roadmap report'. MAVEN (Managing Automated Vehicles Enhances Network), Consortium, Brussels, 2019. Available from http://maven-its.eu.*

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- Infrastructure - It is clear that digital connectivity is the underpinning infrastructure required to enable any ‘Connected’ application that forms the ‘Connected’ part of CAVs. Fibre and V2X are the base level technologies required to deliver both the bandwidth and latency required for robust management of CAVs. Cities, and the private sector, are at varying levels of coverage for fibre across Europe and V2X is currently an evolving technology. Cities will need to continue to work with infrastructure providers to ensure greater levels of connectivity. Cities are, however, more progressed in deploying V2X technologies that enable communications with, and the potential management of, CAVs.

- Planning - Cities are similarly progressed in planning as they are to their progress in policy making, with the two being closely related. There is a significant opportunity for cities to leverage both resident views and invest in modelling capabilities to ensure that services are designed with a focus on people as well as being able to quantify the benefits of different future scenarios to enable better policy and decision making relating to CAVs and MaaS.

- Capacity building - Cities have demonstrated different approaches to capacity planning, with some building in-house capabilities and others ensuring that outsource partners are building capability on the City's behalf. The cities studied are well progressed in terms of capacity planning, which demonstrates that capacity planning must lead development in other areas. Cities should look to increased sharing and collaboration to spread the resource load associated with this capacity building.

- Traffic Management - This is the least developed area of competence for the studied cities. While this is not an issue at present, as no fully automated vehicles are operating on European roads, this is an area of significant opportunity for development and validates the need for the Transition Roadmap as part of the MAVEN project. Cities, their outsourced partners and industry, including MaaS operators, will need to further collaborate on future traffic management capabilities and how traffic management technologies and practices will need to be transformed and developed to allow for the implementation of policies emerging in this area.

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