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CCAM SUMP Topic Guide

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Contents

1. Introduction

To steer a beneficial deployment of Cooperative Connected and Automated Mobility (CCAM) services, ensuring its alignment with sustainable urban mobility goals, local authorities will need to take a leading role. A proactive planning approach is required to effectively regulate how the introduction of Connected and Automated Vehicles (CAVs) should unfold, minimise the potential negative impacts and, more importantly, make the most of the opportunity to influence the paradigm shift into a more sustainable urban mobility vision.

Still, this poses a significant challenge for public authorities. Planning for such an innovative field involves dealing with a lot of uncertainties and understanding the functionalities, requirements, and limitations of the technological solutions. Besides, they need to be able to understand the opinions, needs and concerns of the citizens and stakeholders involved.

Robust guidance, tools and methodologies need to be provided to enable cooperative action and informed decision-making, ensuring the strategic alignment of the deployment scenarios with local conditions, policy goals, and societal needs.

With this in mind, Dynaxibility4CE developed a guideline for the CCAM integration in SUMP processes, leading the preparation of an SUMP Topic Guide for CCAM. Based on the existent Practitioner Briefing for Road-Vehicle Automation, developed by the CoExist project on 2019, Dynaxibility4CE thoroughly analysed current support needs and knowledge gaps, cooperating with ongoing projects like ART-FORUM, PAV and Ride2Autonomy.

Figure 1: AV-Shuttle Pilot on Tartu (Ride2Autonomy)

Moreover, recent experiences, research findings and tools developed, were collected to enhance the planning guidance for CCAM. The results from Leipzig and Stuttgart Region within the project have significantly contributed to such effort, providing valuable examples on how to assess potential impacts of CCAM deployment, test scenarios and develop suitable service models.

2. SUMP Principles for CCAM

2.1. Plan for sustainable mobility in the 'functional city'

Despite the uncertainties, authorities are afforded an opportunity to reflect already today on how they would like to use CCAM to serve their mobility objectives. However, policy makers at EU and national level should provide regional and local authorities with clear regulatory frameworks to start thinking about local/regional policies to best exploit positive impacts of CCAM. It could on the one hand transform the way in which people travel, e.g., people would travel greater distances with faster, more efficient and comfortable vehicles, and on the other hand, also change several aspects of urban mobility planning, e.g. with more data-related planning or a shift in curb side management, which might become more important to plan pick-up and drop-off zones for CCAM services. To manage these transformations, authorities need to understand their nature and consequences, in order to make informed decisions, and learn how to prepare for and influence them as a local or regional authority.

Relevant questions:

- How do institutional and governance structures in local authorities need to change to address CCAM?
- On which institutional level does CCAM needs to be addressed in order to effectively respond to the challenge? And in that sense, how to define the 'functional city', if (1) actions are needed at higher levels (national, regional), and (2) travel behaviour might change, with longer commuter distances, which would expand current Functional Urban Area (FUA)?

2.2. Develop a long-term vision and a clear implementation plan

Authorities today already have to deal with the topic of road-vehicle automation despite the persistent high levels of uncertainties. They should think ahead, clearly define goals (e.g. road space allocation, public transport prioritisation) and link the introduction of CCAM, from the beginning, to their overarching mobility objectives to avoid negative developments that are difficult to change afterwards. A city worth living in must remain the vision. The introduction of CAVs is not an end in itself but shall serve this vision.

Relevant questions:

- How should measures and policies towards managing CAD deployment be implemented, when there are so many uncertainties on how this deployment will unfold?
- How does automation align with different institutional goals and with the city's vision?
- CCAM could introduce various social challenges and affect liveability. How would this affect the city's vision and policy goals?
- How could liveability, including equity and accessibility, in cities be affected by CCAM? What can cities do mitigate potential issues?

2.3. Assess current and future performance

Due to the lack of experience with CCAM in urban areas and reliable data, assessing the impact of CAVs is more like crystal ball reading. While it may bring some benefits, such as improved traffic performance, increased space efficiency and less accidents, there is also the possibility that it could lead to increased congestion, negative environmental and health impacts, and the discouragement of public transport, walking and cycling. Methodologies like SWOT analysis and scenario development foster discussions and consensus on potential impacts of CCAM, but they require appropriate tools to analyse its effects in urban mobility. Fortunately, more and more research projects dealing with the topic, are developing methods and functionalities to enable modelling transport with CAVs and the evaluation of its impacts.

Relevant questions:

- Considering the high degree of uncertainties, how should CCAM be considered in transport assessment today?
- What are the basic scenarios that should be considered in SUMP 2.0 and European cities?
- How can cities develop base scenarios for CCAM deployment?
- How to consider/assess the effects of CCAM in traffic flow and travel demand? How can it be modelled and what obstacles/difficulties arise?

2.4. Develop all transport modes in an integrated manner

CAD should be included into an integral mobility strategy, with high capacity public transport as a backbone and encouraging walking and cycling. Based on such a balanced and coordinated multimodal mobility offer, CCAM can support excellent options for sustainable door-to-door mobility. In this way, the safe interaction with other road users is a key issue, and positive impacts like traffic efficiency gains may only materialise in the medium to long-term, once CAVs are well tested and the penetration rate is high. The interim transition phase might then prove less beneficial, as CAVs face pedestrian crossings with pedestrians, conventional vehicles, or other road users. Furthermore, it is not inconceivable that a potential growth of shared services with CAV-fleets, may herald the end of public transport as we know it today. Consequently, a transformation of public transport, aiming to exploit the advantages of CCAM (e.g., significant reductions in operational costs), with new business models and mobility services, needs to be considered. In such scenarios where CCAM leads to fewer privately owned cars and public transport services, and accordingly to less revenues from parking fees and fines, as well as from public transport tickets sale, authorities would need to create new streams of public income and fitting business models, thus ensuring adequate provision of public transport services and relevant city infrastructure.

Relevant questions:

- How does CCAM relate with, and affect, each different transport mode, and which changes could it bring to urban mobility and accessibility?
- How to assess the interactions of automated vehicles with conventional vehicles and other road users, in a mixed road environment?
- How does it affect the business/operating models of other modes of transport (both public and private)?

2.5. Cooperate across institutional boundaries

CCAM based mobility needs a system approach and cannot be planned by transport authorities alone. It is important that authorities re-assess the required competences to enable the planning of a sustainable urban mobility offer based on CCAM. In addition, cross-department cooperation, including for example urban/spatial planning, environmental, economic affairs departments, is needed. New institutional structures like horizontal working groups / departments or even cross-border urban mobility managers (that allow the integration and coordination of public transport, new mobility services and platforms), as well as new skills and competences, e.g. data handling and analysis, are needed to plan and introduce CCAM.

Relevant questions:

- How do institutional structures in local/regional authorities need to change to address CCAM?
- What are promising cooperation and governance models to address CCAM, considering the rising significance of data availability and management?

2.6. Involve citizens and relevant stakeholders

CCAM can help to develop a transport offer in FUAs combining high capacity collective and individual services that responds to citizens needs and delivers on public goals like accessibility, inclusion and liveability. Authorities should lead this path, discuss solutions and create synergies with various groups of relevant stakeholders, such as vehicle manufacturers, technology and transport service providers. Authorities should also involve citizens by polling their acceptance and promote their active involvement through awareness raising and informative activities (e.g. WISE-ACT open events: https://wise-act.eu). Pilot demonstrations are also a valuable tool in this regard, and help illustrate more clearly the challenges and benefits of CCAM.

Relevant questions:

- How do you facilitate a participatory social dialogue about such a complex and technical topic with so many uncertainties?
- How to allow an effective/beneficial discussion around automation, considering low levels of awareness and knowledge of the topic, and the complexity of handling the related ambiguities?
- Who are the stakeholders that should be involved in planning for CCAM and new mobility services, e.g. CCAM service providers? And how should authorities engage with them?
- How can business opportunities effectively serve citizen needs?

2.7. Arrange for monitoring and evaluation

Cooperative, Connected and Automated Driving, and the transformation of urban mobility through its implementation on different transport modes (both public and private, and for passenger as well as freight transport), should be evaluated in the same way conventional modes and technologies are: by monitoring it's impacts on overall mobility objectives, e.g. modal split shift towards sustainable modes, and ensuring a better quality of life. However, the technological differences in CCAM do require the identification of adequate metrics to assess its impacts, and cities need to consider changes in their planning practices to ensure its monitoring and evaluation is done correctly. Considering the its potential effects on urban mobility, KPIs for such evaluation could be traffic flow efficiency, space efficiency or safety. Besides, authorities should be prepared to collect relevant data for the CCAM performance monitoring. Therefore, it should be ensured that different mobility services can communicate to avoid closed systems.

Relevant questions:

- Considering the high degree of uncertainties, how should CCAM be considered in transport assessment today?
- What indicators best measure the impact of CCAM, in accordance to each city's policy goals?

2.8. Assure quality

Following the SUMP process and answering the relevant questions listed in the present document itself can be considered as a quality assurance approach. In addition, exchanging knowledge and experience with FUAs that made already experiences with CCAM pilots and trials should be encouraged. Authorities should adapt given regulation to allow testing of CAVs to take advantage of insights and learnings based on CCAM-related innovations.

Relevant questions:

- How to plan effectively and make informed decisions on an uncertain and still developing topic?

- How to plan for innovations (even before their deployment)?
- How to ensure CCAM deployment and resultant mobility services are in line with the overall SUMP objectives?

3. CCAM in SUMP processes

This section reflects in the main factors and key questions that need to be considered to effectively include cooperative connected and automated mobility (CCAM) in the SUMP process, aiming to support and empower planning practitioners and mobility stakeholders, to take on the challenge of actively addressing CCAM in their mobility planning practices. By reducing uncertainties and sticking to the core planning principles, local authorities can take a leading role, rather than merely being observers of the technological developments

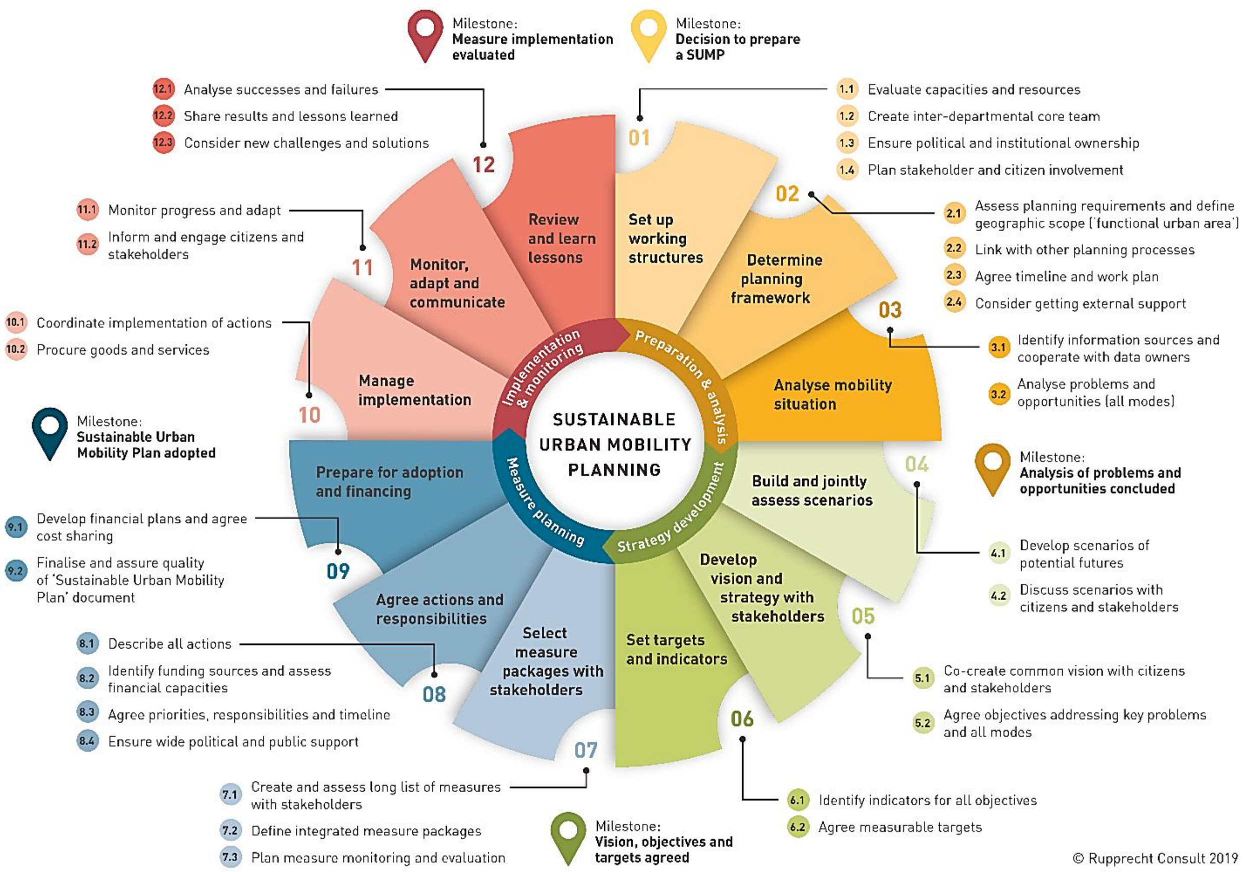


Figure 2: SUMP Cycle (Rupprecht-Consult, 2019)

3.1. Phase 1 – Preparation and analysis

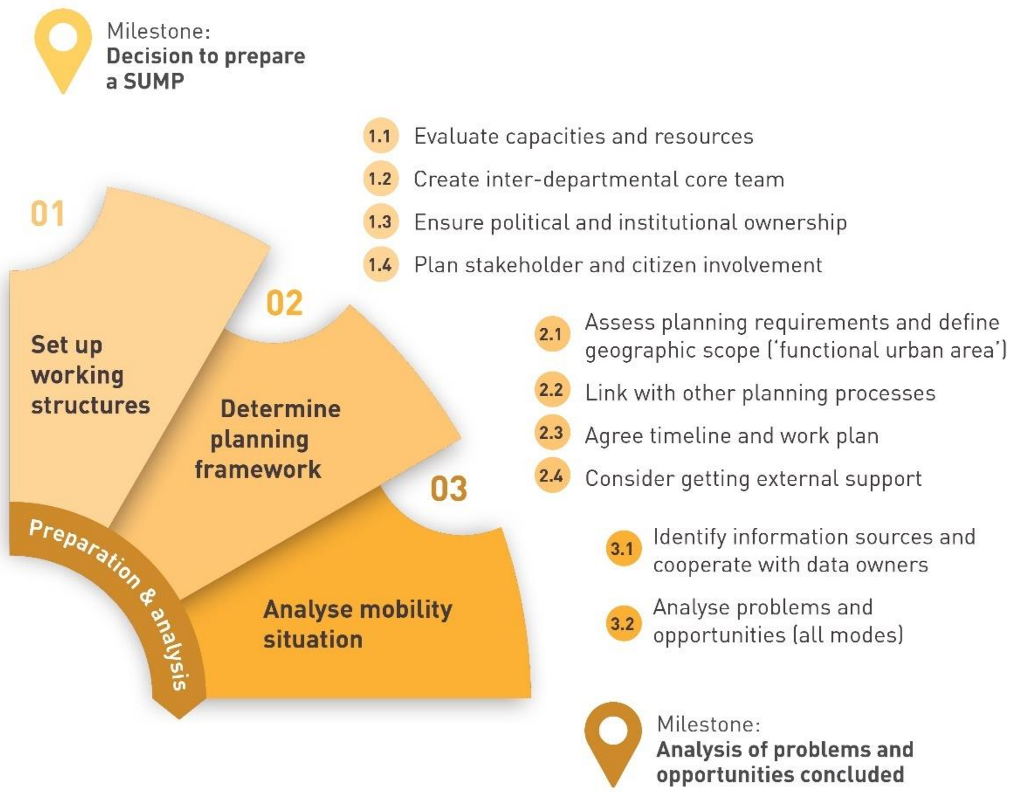


Figure 3: SUMP-Phase 1 (Rupprecht-Consult, 2019)

3.1.1. Setting up multi-actor commitment and cooperation for the functional city

The success of the transition towards higher penetration levels of CAVs will largely be determined by integrating them into existing sustainable urban mobility planning processes (i.e. SUMPs). However, today there are hardly any strategic transport plans in Europe that properly address the technology and the resulting impacts. Incorporating CCAM into SUMP processes, requires an explicit decision and a strong commitment to address the challenges and opportunities that it generates, and adequately prepare to handle them.

A broad participatory approach is key to ensure that CCAM is being deployed to the benefit of all and not the few. Not one single actor is able to find the answers to all these complex issues. An effective working structure needs to be established, ensuring the active participation of citizens and key stakeholders, whilst steering institutional cooperation and coordination at different government levels. Furthermore, structured coordination and information exchange among cities, at the national, European and global scales, is fundamental to establish consolidated needs and harmonize markets, allowing the creation of economies of scale that ensure the optimal development of new mobility services. The European Commission strongly supports such exchange, and has set up an informal group of experts, the *Single Platform for open road testing and pre-deployment of cooperative, connected, automated and autonomous mobility* consisting of up to 100 experts and appointed for a period of three years, which will provide advice and support to the Commission in the field of testing and pre-deployment activities for Cooperative, Connected, Automated and Autonomous Mobility – CCAM (European Commission, 2019).

Citizen participation helps to understand the needs of the future users of the system and to cater to them, also giving an opportunity for the municipality to understand how mobility services can be improved, and in particular, how connected and automated vehicles can be of help in the future transport systems by improving accessibility and equity of services. Providing a platform for citizens to be heard, increases acceptability and furthermore, the perception of users gives an insight about the possible threats (e.g. reduction in the value of travel time, since it can actually be a productive time and increase comfort of CAV usage) and enhances proactive mitigation strategies (e.g. pricing schemes) by engaging citizens as part of developing a common solution. An example of this is the UK Autodrive project (UK Autodrive, 2017) that conducted a public attitude survey (see case study below) or the WISE-ACT citizen survey across Europe conducted in 2019.

Planning for AVs and reducing uncertainties also requires the involvement of stakeholders that are not traditionally part of mobility planning. Municipalities alone cannot solve mobility challenges and thus need to collaborate with mobility service and technology providers from the private sector. Engaging with OEMs, technology companies, and new mobility service providers is an important aspect in co-creating solutions that benefit all: businesses, government, operators, and people. This also helps in developing a common vision between often conflicting objectives of different organisations, when planning for the future of mobility in cities. Cities and authorities will get a chance to have a better understanding of the topic, and increase their capacity to implement the right policies and regulations to support innovation and restrict unfair competition. Examples of platforms bringing together stakeholders from different areas are Antwerp's Marketplace for Mobility (Van Der Pas, 2017), Gothenburg's DriveME (City of Gothenburg, 2017) (see **Error! Reference source not found.**) or – on a higher level - the German platform for urban mobility (Plattform Urbane Mobilität, 2017) which involves cities and OEMs for developing jointly mobility solutions for the future. Bringing together different stakeholders' knowledge will foster innovation development in terms of the application of new technologies and opening up new markets for building win-win-situations for the involved stakeholders. Still, besides the involvement of cities and industry partners, the participation of civil society groups is important to increase acceptability and help co-create solutions that are user-centric.

3.1.2. Assessing resources and opportunities

Planning for such an innovative field involves becoming aware of the technological advancements and capabilities of connected and automated vehicles (and the associated features) and understanding the opinions, needs and concerns of the citizens at an early stage. The key here is to develop an awareness of what the deployment of automated vehicles and resulting impacts means from a local authority perspective.

Besides, innovations for sustainable urban mobility solutions are more often based on data (and linked information and knowledge) than on concrete or physical infrastructure. Planning of sustainable urban mobility, in particular in a data-heavy environment of CCAM-based solutions, needs to be aligned and should keep up with technological advancements to be able to effectively and proactively plan for future technological changes that impact mobility in cities.

Local practitioners responsible for planning and managing mobility in cities, will have to develop new skills and competencies regarding modelling and impact assessment of automated road transport, data analysis and management, the later of particular relevance considering the General Data Protection Regulations – GDPR (Contantini, et al., 2020). More and more new technologies available for deployment in supporting traffic management, e.g. C-ITS, will become available and authorities and cities need to ensure that technical capacities are up to the level to be capable to use new tools and deploy state-of-the-art measures. Lessons learned from activities in other projects and cities, also allows to reach a better understanding of the related challenges and opportunities. The ARCADE project holds an inventory of all CCAM related activities at EU level (ARCADE, 2019). Developing and using common terminology is of paramount importance and initiatives such as the WISE-ACT Glossary contribute in meeting these objectives.

SUMP Central European Competence Centre

SUMP-Central was developed and created in the LOW-CARB project as a European competence platform for sustainable urban mobility planning (SUMP) to raise awareness on the topic of SUMP and encourage cities to start this process by showing good practices. Thus, the SUMP-Central provides knowledge, resources, and content to support the specific development of SUMPs in regions of central Europe (CE) in local central European languages. As a one-stop knowledge database of news, good practices, exemplary SUMPs, tools and resources for local planning authorities and urban practitioners, it caters to practitioners and students looking for:

- helpful learning materials or educational resources about SUMP processes and innovative mobility,
- information about national policies on SUMP in central Europe,
- practical tools to evaluate SUMP processes and make them more efficient,
- find funding opportunities and experts in the field of sustainable urban mobility planning.

Also, the tool is taken up by different CIVINETS such as the as the MAGYAR civinet, the civinet Slovenia-Croatia, the German speaking civinet and currently also the Civinet Romania (extending the current central European to the Balkan area), to disseminate information, news, events, or to use it entirely as their new Homepage. As the platform connects news from the field published by the civinets into all languages, a comprehensive general news overview can be accessed in all central European languages. Furthermore, the platform will be potentially used by national task forces and linked with national SUMP platforms.

SUMP-Central goes a step further to offer access to expert networks within central Europe and beyond, who have the experience of establishing low carbon mobility schemes in these distinct regions who are just at the beginning of their transition. Thus, the platform does not seek to replace other platforms but to rather create a link to the existing SUMP databases by bridging the knowledge gap encountered by CE-planners.

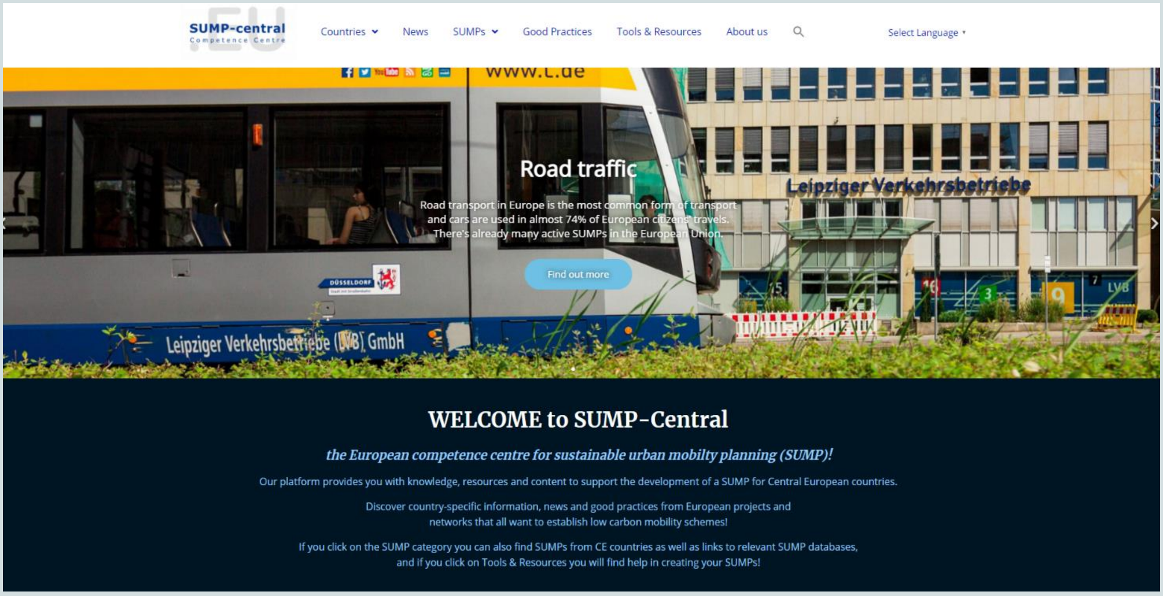


Figure 4: SUMP-central platform

3.1.3. Analyse problems and opportunities

When talking about CCAM, it is vital to recognise the context of generalised uncertainty that currently characterises its particular planning conditions. In this sense, the focus lies much more on flexible and diverse scenario development and the assessment of their potential impacts, than when dealing with other modes of transport. CCAM also poses a higher technological-focused context, which calls for additional knowledge.

System Model analysis for the diagnosis of mobility and organisational context

To analyse the current situation in each FUA and as a basis for action planning towards the implementation of low-carbon innovative mobility solutions, Dynaxibility4CE has conducted diagnosis trainings sessions. In this way, a clear understanding of the current "readiness level" of the city should be achieved through a critical examination of the organisation and joint analysis of the changes required to enable informed decision-making on the deployment of new mobility solutions.

To deal with the complexities of the mobility innovations addressed and their integration in urban transport systems, this diagnosis followed a structured analysis through the systemic change management model OSTO which stands for Open, Social, Technological and Economic (based on German terminology "Ökonomisch) system parts in a holistic System Model perspective. In practice this model was used as a managerial and reflection tool and used in Dynaxibility4CE to facilitate managing the steadily increasing dynamism and complexity of mobility systems and to find new action strategies to plan transformation towards innovative low-carbon or zero-emission mobility systems respectively. The project follows the structural version of the model and focuses on eight design elements and (system-) behaviour:

- **Technology:** The technological design component includes technical machines, equipment, buildings, etc. (material resources) and their interrelationships, i.e. all material and spatial features.
- **Organisational:** The organisational system describes the structural and procedural structure, i.e. functions, hierarchies, subordination relationships as well as the regulation of the processes in terms of time, space and facts.

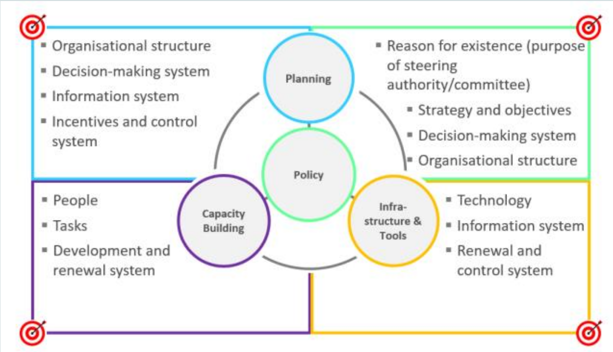


Figure 5: Interactive workshop categorisation scheme

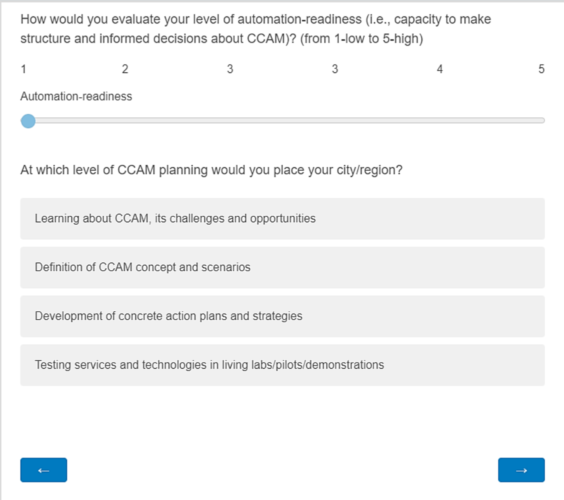
- **Tasks:** This includes all individual tasks and their division into subtasks in the form of concrete assignments, expectations of functions, jobs, etc.
- **Decision-making system:** Describes where, how, by whom, at what level, at which position and with what tools decisions are made. It also describes which mechanisms control the decision-making processes.
- **Information system:** The information system describes who, when, from whom, with which tools, receives which information - or which not - and why this is so.
- **Incentives & Control system:** The reward and control system include both material/immaterial and formal/informal reinforcement and mitigation systems.
- **Development & Renewal System:** Through the development and renovation system, the flexibility, performance and adaptability of an organisation are maintained and continuously developed.
- **People:** Members of the company or organisation and their roles (talents, qualifications, etc.), material expectations and needs. Socio-emotional relationships and interaction conditions ("environment") are also included.

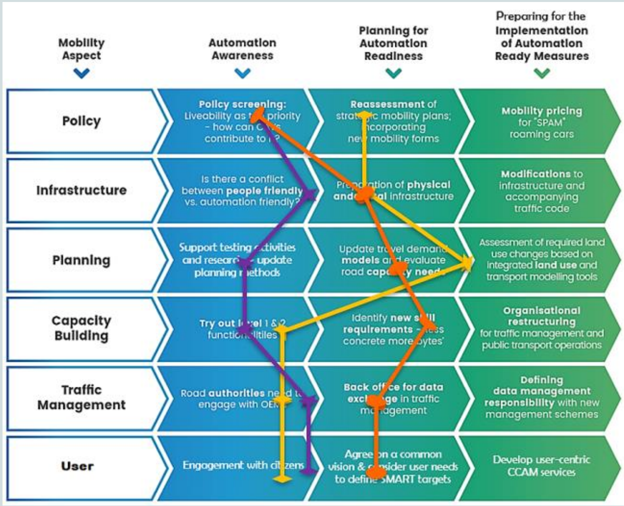
The described conditions, commands for a detailed analysis of the effects CAV could have on the current mobility situation, and its relation with all modes of transport. The potential (positive or negative) effects on public transport need to be carefully considered. Besides, it requires the knowledge of state-of-the-art developments in the field and learning from relevant experiences of other cities in their attempts to address CCAM. Still for several years to come, cities will have to manage a mixed-road environment, where CAVs and conventional vehicles will need to co-exist, and also safely interact with other road users. This will raise not only technical and operational challenges, but also in terms of the normative context. It is also important to perform an analysis of the current legal framework and its relation to CCAM, identifying gaps in the regulation (Contantini, et al., 2020) and steering the discussion across political levels.

CCAM-readiness Self-Assessment Tool

The Dynaxibility4CE project has developed an CCAM-readiness Self-Assessment tool to guide authorities in evaluating where their city stands in relation to CCAM deployment and what the next steps could be to get 'automation-ready, i.e., having the capability to make structured and informed decisions about the comprehensive deployment of CCAM.

As proposed by the Automation-ready Framework (CoEXist, 2020), depending on the local conditions and objectives, each city might find themselves in a different phase of action: (1) automation awareness creation; (2) planning for automation-readiness; or (3) preparing for the implementation of automation-ready measures. With this in mind, the questions in the self-assessment tool are tailored to support practitioners in assessing the applicable phase(s) of automation-ready planning for their FUA. It is meant to facilitate the preparation of the planning process and analysis of the contextual conditions. And supports the assessment of available capacities and resources to carry out the planning activities and later implementation, including human resources (i.e., available staff and skills) as well as financial resources.





Due to the high levels of uncertainty and complexity associated to CAV, authorities often have trouble understanding where to start, what types of strategies and measures are recommended or possible to address CCAM. The self-assessment tool provides a simplified entry point for planners, supporting in the assessment of key questions to assess local challenges, opportunities, risks, and requirements for the deployment of CCAM services. The tool mainly targets (transport) planners and working for local and regional public authorities, who do not necessarily have deep knowledge on automation technology. But it will also be useful for mobility service providers, researchers, academia, and other stakeholders. It guides them towards the most relevant information on planning for automation in their context, raising awareness of existing tools and resources, and on how to integrate them into the SUMP processes.

Automated drivability: assessing urban street networks

With the deployment of CCAM keeping below initial expectations, it became apparent that CAVs are going to be fit for some roads earlier than for others. As part of the research project Avenue21 at the TU Wien, an index was developed to assess the suitability of existing streets spaces for automated driving systems from a technical-infrastructural perspective. Although intentionally modelled similar to "walkability" or "bikeability" indices, the "automated drivability" does not represent a development goal in itself (i.e., higher automated drivability being more desirable), but is an analytical tool for urban mobility planning, capable of taking the distinct local context into account. The index provides evidence for critical challenges transport infrastructure planning will face, if CAVs are deployed unevenly in metropolitan regions (Mitteregger, et al., 2019).

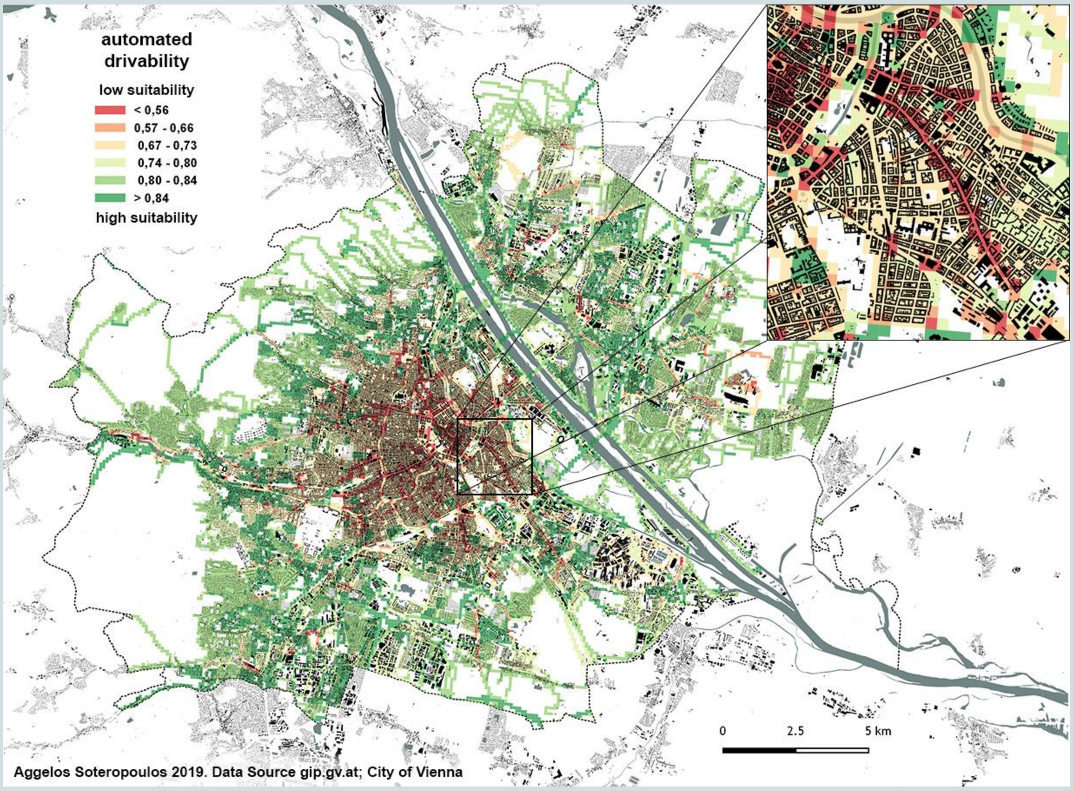


Figure 6: Automated drivability assessment for the City of Vienna (Mitteregger, et al., 2019).

3.2. Phase 2 – Strategy development

Figure 7: SUMP-Phase 2 (Rupprecht-Consult, 2019)

3.2.1. Scenarios for CCAM in your city

When drawing up the potential future mobility conditions in the city, in relation to a field with such unclear perspectives as CCAM, it is important to consider various possible scenarios, reflecting on the variety of factors and dimensions define them (such as, for example, proactive planning, car-ownership, individual travel behaviour and ride-sharing), and then comparing the benefits and threats against each other.

To do so, it can be helpful to consider the perspectives of each different impact group, such as citizen's, local authorities, transport operators, and other businesses, among others. Table 1 (Thomopoulos & Givoni, 2015) presents the expected impacts benefits and threats of a future deployment of AVs, for users, businesses, and governments.

Developing and illustrating possible future scenarios is a step towards understanding the potential benefits and drawbacks of introducing a certain technology into the transport system. Prioritising certain future scenarios can also be a guide on how to develop policies and pilots to reach that scenario.

Integration of autonomous ridesharing shuttles into the public transport system (Stuttgart Region)

VRS elaborated on “the Integration of autonomous on-demand ridesharing shuttles into the public transport system in a peri-urban area in Stuttgart Region” through a transport model study, conducted by the University of Stuttgart as service provider. Due to the fact that the technology of autonomous vehicles is at a stage of time where still a lot of research and development is required, transport model studies and simulations have great potential to lay ground knowledge on the impacts of such new and innovative mobility solutions. The study assumed that the autonomous on-demand shuttles drive as fast as regular cars nowadays, that the road infrastructure is completely set up to allow for autonomous driving and that passengers accept autonomous cars without objections.

The ridesharing offer, simulated in three scenarios in the transport model study, served as a feeder to the regional and suburban train in the north and south of the planning area called ‘Schurwald’.

A	Scenario 0	Base scenario of the prognosis horizon 2030
B	Scenario 1	Substituting the regular bus lines with an implementation of the autonomous Ridesharing shuttles in 15 min. service frequency. Passengers are picked up at the regular bus stops.
C	Scenario 2	Substituting the regular bus lines with an implementation of the autonomous Ridesharing shuttles in 15 min. service frequency. Passengers are picked up at their place of choice.
D	Scenario 3	Combination of three regular bus lines and autonomous Ridesharing shuttles in 30 min. service frequency. Passengers are picked up at the regular bus stops.

After completing the various project phases within ‘Dynaxibility4CE’ VRS draws the conclusion that, new innovative mobility solutions such as CAD and MaaS enhance political stakeholders to strengthen public transport also in peri-urban areas among FUAs in central Europe. The conducted transport model study showed that especially autonomous vehicles, functioning in a ridesharing system, allow an individualization of the population’s transport demand whilst at the same time bundling passengers. Consequently, an extended comprehensive basic offer of the public transport is guaranteed for every group of society. Besides, it turned out to work beneficially to integrate for instance ridesharing offers into the public transport system to create synergies by using it as a feeder to train lines. By closing the first and last mile gap to train lines, an environmentally friendly connection is established. It also enables the users to move around without using or even owning a car at all.

The ‘Schurwald study’ pointed out, that it is possible to decrease the share of the private car usage by substituting it remarkably with ridesharing shuttles. Further, it is of advantage to combine on-demand systems such as ridesharing with several regular buses to save unloaded transport kilometres, energy and costs. In order to implement such an autonomous and on-demand ridesharing shuttle, stakeholder engagement is key. Especially since the new Passenger Transport Law entered into force, clear legal guidelines for the implementation of such mobility offers have been defined. As a result, districts and district-free cities are the main responsible authorities which set the rules for scheduled and bundled on-demand offers.

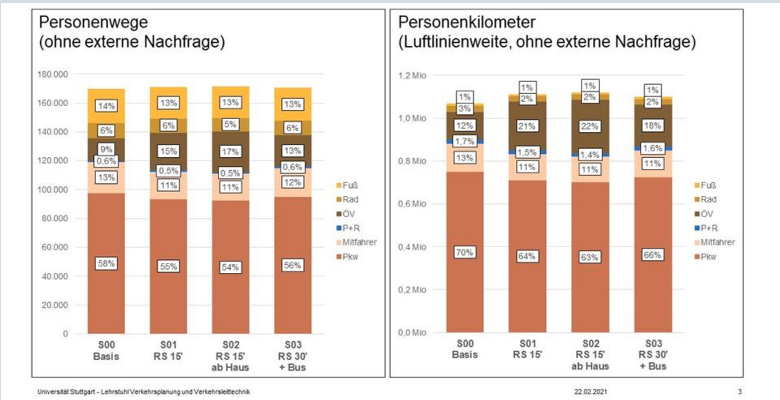


Table 1: Expected impacts on future mobility facilitated through CCAM, per impact group (Thomopoulos & Givoni, 2015)

Impact group		Benefits
Impact group	User	Travel time is not driving time, so disutility decreases and comfort increases.
	User	Travel time may be used for other work/leisure activities.
	User	AVs can allow the integration of culturally diverse users in cities globally.
	User	AVs can enhance demand for travel allowing passengers of any age to reach their destination safely
	User	Transport related social exclusion may be eliminated
	Government	Increased safety due to less accidents (mainly in the era when only AVs will be on the roads)
	Government	More parking space will become available and it may be used for other purposes by city authorities.
	Government	If AVs are eco-friendly, there could be reduced air pollution and lower energy use from the transport sector.
	Government	Accessibility can improve for all travellers, including the elderly and disabled.
	Business	Significant business opportunities will arise for automotive manufacturers, particularly for conventional ones which decide to enter this innovative market.
	Business	Expanding databases and innovative use of Big Data will allow the emergence of business opportunities and new business models, creating value for stakeholders.
	Business	Logistics and supply chain business will reduce (congestion, time) costs through eco-driving, better route planning, V2x communication and platooning.

Impact group		Threats
Impact group	User	High cost of 'smart' infrastructure (V2I) to accommodate AVs.
	User	Local congestion may increase if the aggregate number of journeys increases.
	User	Cost of emerging mobility patterns can lead to social exclusion of certain groups if high.
	User	Identifying and assigning responsibility for car accidents may become fuzzier.
	User	'Digital divide' can lead to increased social exclusion.
	User	Better use of travel time may increase travel time e.g., daily commute, resulting in higher aggregate energy demand at local and national level.
	User	Widespread use of AVs can reduce walking and cycling, increasing obesity and negative health impacts.
	User	Unintended consequences will arise such as privacy, surveillance and data management issues linked with ICT for transport or the threat of wireless hacking to gain unauthorised control of AVs.
	Government	The adjustment period when both conventional human driven and autonomous cars co-exist on roads could impose more car accidents.
	Government	Deciding on the optimal route will be a challenge particularly during extreme events and principles may differ across cities complicating inter-urban journeys.
	Government	Emergence of diverse technologies by competing actors may lead in lack of coordination and common legislation.
	Government	Reduced employment demand for drivers and car technicians, increasing government costs for retraining and/or unemployment benefits.
	Business	Better use of travel time may increase travel time to travel through routes with greater journey comfort leading to increased congestion.
	Business	Development of competing technologies by diverse actors may lead to inefficient use of resources and the evolution of competing standards internationally.
	Business	Vehicular communication network needs high transmission capacity equipment and proper penetration rate to achieve optimal transport performance.

SPACE Toolkit

SPACE (Shared Personalised Automated vEhicles) is the flagship project from UITP, with the goal of establishing public transport at the centre of CCAM deployment. The project is developing a toolkit which integrates all required knowledge on shared automated vehicles (AVs), guiding authorities and mobility stakeholders to successfully integrate AVs with public transport.

Figure 8: SPACE Project – AV progress map (UITP)

The SPACE Toolkit focuses on four aspects of CCAM:

- Practical scenarios and how to get there: guidance scenario development where fleets of shared AVs are integrated into public transport, for urban, suburban or rural settings.
- Technical specifications of AVs: technical requirements for the deployment of scenarios identified.
- AV pilots and initiatives around the world: interactive map shows the progress of shared AV initiatives around the world
- Impact assessment: of AV's integration with public transport, on matters such as customer experience, human resources, business models, operations, digital infrastructure, urban space and legislative framework.

3.2.2. Cooperative vision development

Setting a vision clarifies the priorities that you will have as a city. Clearly addressing new mobility solutions based on CCAM does not just set a path to exploring new solutions in tackling current and future challenges in mobility, but also makes the ambitions of a city clearer to other stakeholders and potential independent developers interested in becoming part of the solution. Examples for identifying different potential governing scenarios of CAV rollout and prioritising scenarios that are desirable in relation to the sustainable mobility goals of a country are documented – inter alia – for Austria (bmvit, 2016), Sweden (KTH Royal Institute of Technology, 2017) and Germany (BMVI, 2015).

An example of a city developing a vision for the future with CCAM is Milton Keynes, UK (Milton Keynes, 2018). Milton Keynes developed a Mobility Strategy as a reference point for how the town wishes to maintain, improve and develop its transport system up to 2036. It also shows how Milton Keynes wishes to begin investing in the short term in the development of the town's long-term future transport system to 2050 to ensure connectivity to new infrastructure projects. The strategy includes the ambition to "develop and promote a 'First Last Mile' culture for future technologies such as autonomous and connected vehicles and sustainable connectivity".

International Citizen Debate on Driverless Mobility (Mission Publiques)

With a team of partners, Missions Publiques ran the first of two phases of an international and local citizens' dialogue processes in 2018 and 2019, where cities from Europe, North America, and Asia hosted deliberations focused on scenario building, trust, and policy.

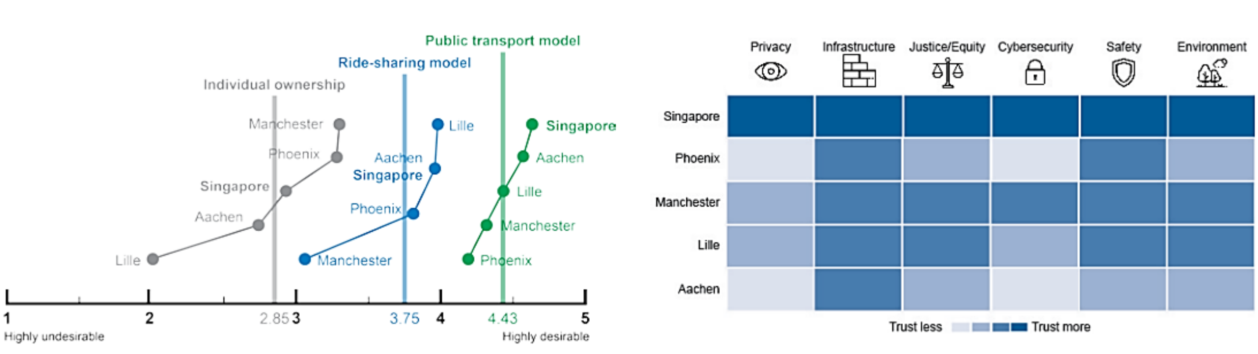


Figure 9: Results Citizen´s Debate on Automated Mobility. Singapore (SUTD, TUM)

Automated mobility was one of the key topics of interest. As part of the international consortium of the citizen's debate on driverless mobility, the City of Aachen joined up with RWTH Aachen University to host a debate with 100 of its citizens. Similarly, automated mobility was the topic of a citizen's dialogue in five Austrian cities, led by AustriaTech. Almost 170 people attended the events in Vienna, Linz, Graz, Pörtschach and Salzburg to discuss the potential of this new technology. Representatives from AustriaTech and the City of Aachen, participated in the CoEXist coordinated session at the CIVITAS Forum 2019. The presented approach included a strategic focus on potential future scenarios to engage in an informed analysis with citizens.

Figure 10

3.2.3. Measurable targets and co-created mobility strategies

Once a vision has been agreed upon, cities should define detailed mobility objectives, targets and indicators that will guide the planning process, and co-create a 'mobility strategy' with stakeholders and citizens, considering all modes of transport in the entire urban area. In the case of CCAM, this raises various challenges, as cities might struggle with the definition of realistic strategies, measurable targets and adequate indicators to assess progress of such an unknown and complex field. These are some of the questions that the CoEXist project attempts to answer, defining metrics to assess the impacts of CCAM in urban transport, in regard to traffic performance, space efficiency and safety. Furthermore, in its goal of supporting cities to make structure and informed decisions about the comprehensive deployment of CAVs, CoEXist has developed an Automation-ready framework, which recommends a series of phases, and concrete measures, to facilitate the reduction of uncertainties and to ensure a smooth transition into the sustainable deployment of CCAM in cities. An overview of these guiding factors to be considered in the city's strategy development is presented in the figure below.

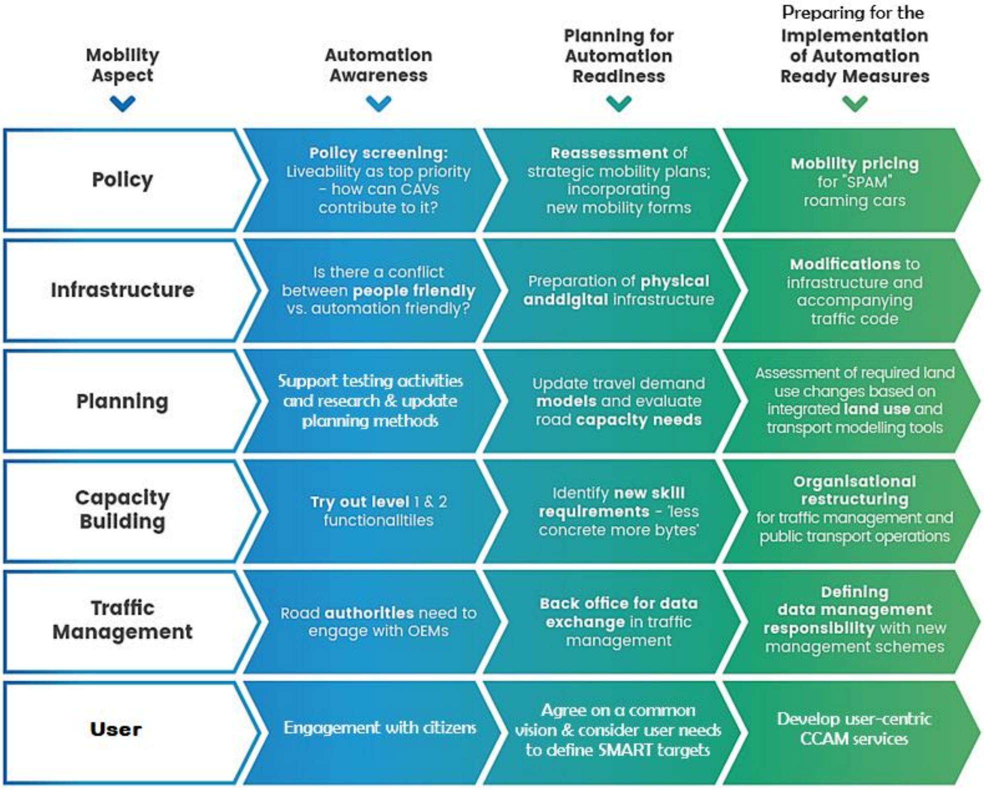


Figure 11: CoEXist's overview of phases towards automation-readiness, with measure examples (CoEXist, 2018)

3.3. Phase 3 – Measure planning

Measures that should be considered towards an effective and comprehensive deployment of CCAM range across various fields of action, including institutional transformation, adaptation of transport planning practices, development collective mobility services, optimisation and strengthening of public transport, setting an adequate policy framework, and the potential adjustment of the city`s infrastructure design to better exploit the advantages of CCAM (e.g., pick-up/drop-off areas and high-quality public space instead of parking spots). It's worth noting that the adaptation of the road infrastructure should not be required for correct functioning of automated road vehicles, but strategic changes might allow to fully exploit the benefits of this technology.

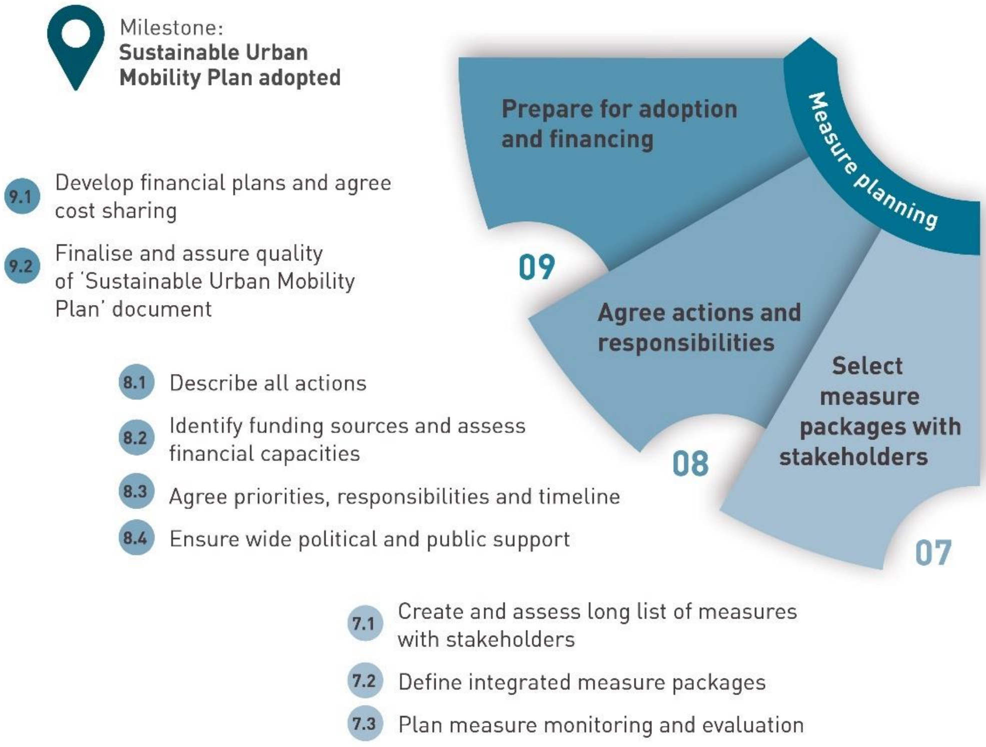


Figure 12: SUMP-Phase 3 (Rupprecht-Consult, 2019)

3.3.1. Institutional adjustments

Institutional adjustments are expected to happen in the future due to the changes that are likely to happen in relation to the increased deployment of intelligent transport systems, CCAM and MaaS services within the transport network of cities. This can be within institutions or agencies or maybe an entirely new department and will heavily depend on the nature of the policies and regulations and the measures that are adopted in relation to connected and automated vehicles. For example, if CAVs are to operate as fleets controlled by operators, perhaps a new setup for traffic management units would be required. Government agencies could also be needing internal information and technology departments to deal with technical communications necessary with such traffic management or control units. Furthermore, issues of privacy and cyber/security should not be neglected when planning such institutional adjustments.

Governance and organisational adjustments: Automation-ready Forum Stuttgart

Planning for CCAM concerns many different aspects of a municipality. Due to the multitude of different questions that have to be asked and answered in connection with this new form of mobility and the (new) tasks that have to be mastered, it is essential that the different organisational units concerned with their different responsibilities, work hand in hand.

In order to ensure the most constructive and effective cooperation between different authorities and responsibilities, the City of Stuttgart has long established a dedicated working group, called the "AG Mobilität" (Mobility Working Group), which aims for a holistic and competent design of mobility, and its contribution to a sustainable urban development strategy.

Figure 13: Automation-ready Forum in Stuttgart (CoEXist)

During CoEXist, the organisational units in Stuttgart have extended their level of expertise concerning automated driving. Therefore, the framework of the Automation-ready Forum was used to reflect the working methods of this expert group, critically assessing the city's automation-readiness. The main aim of the Automation-ready Forum was to create a uniform, knowledge-based understanding of the chances, possibilities, and risks of CCAM deployment. This included defining, and raising awareness on, the roles and responsibilities of every affected internal organisational unit.

The Automation-ready Forum confirmed that the complexity of achieving automation-readiness, and how various competences and responsibilities in a municipal administration need to be addressed. Therefore, the activities of the specific units have to be linked and coordinated. A continuous exchange of expertise and activities has to be established. In addition, human and financial resources must be provided to guarantee a continuous work – concerning strategic, planning, administrative and technical aspects.

3.3.2. Physical and Digital Infrastructure

Infrastructure adjustments, whether physical or digital, will likely be necessary in order to improve traffic efficiency and safety for all modes in the transport network, as CCAM is deployed and higher penetrations rates are reached. Specific infrastructure adjustments need to be made in accordance with the mobility requirements in the different heterogeneous sections of the network. For instance, there might be changes needed for transition zones, where vehicles have to shift from an automated to manual mode. Transport models can test the necessary infrastructure adjustments that are needed to make transport networks more efficient and, in many cases, to make mobility safer for all modes. An AV-ready modelling environment will support sound decision-making.

Infrastructure classification Scheme for Automated Driving (ISAD)

Understanding road infrastructure automation-readiness and its relation to CAV's Operational Design Domains, is of vital importance to steer CCAM deployment and plan for the transition phase. Shifting the focus from vehicle functionalities to infrastructure characteristics, can facilitate authorities' understanding of the challenges and limitations of automated driving. The H2020 project INFRAMIX has developed an Infrastructure classification Scheme for Automated Driving (ISAD), which categorises roads according to the amount of support they provide for CCAM, from class E to A, as seen in Figure 17. Enhanced capabilities of road infrastructure will be instrumental to enable coexistence of vehicles with different automation levels and exploit the expected benefits of CCAM.

The ISAD presents a valuable tool to further evaluate deployment scenarios, coupling the infrastructure requirements with the potential CCAM services to be implemented, to deliver concrete guidance for cities. For instance, CoEXist's results have showed how traffic performance can be negatively affected by the introduction of CAVs during the initial transition period. It is up to cities to define the CCAM services, the type of mobility system and solutions that wants to implement, and finding the right mix of infrastructure development, regulations, and business models to achieve that vision.

	Level	Name	Description	Digital information provided to AVs			
				Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance: speed, gap, lane advice
Digital infrastructure	A	Cooperative driving	Based on the real-time information on vehicles movements, he infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow	X	X	X	X
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time	X	X	X	
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs	X	X		
Conventional infrastructure	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs	X			
	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs				

Figure 14: Infrastructure Support for Automated Driving - ISAD classes (INFRAMIX, 2019)

3.3.3. Collective mobility services

In the future, services will be more integrated and multimodal. It is important that despite the comfort of CAVs, collective high occupancy shared mobility services should be encouraged and become the priority over privately owned or single occupancy CAVs to reach sustainable urban mobility goals in cities. New multimodal collective mobility services should also be subsidised as early as possible, if costs are to remain competitive, but this will mostly be determined by the business models that are to come in conjunction with such services. The UITP Policy Brief on 'Autonomous vehicles: a potential game changer' (UITP, 2017) clearly sets out that cities need to support collective and inclusive mobility solutions for CAVs and a culture of sharing to avoid an uncontrolled deployment of CCAM leading to single occupancy or empty CAVs in city centres in the future.

Pilot demonstrations of AV-shuttle services in Europe

The EU-funded project Ride-to-Autonomy aims to demonstrate autonomous shuttles' integration into the transport system in ten EU cities: Aveiro (PT), Barcelona (ES), Contern (LU), Esch (LU), Inverness (UK), Pfaffenthal (LU), Reggio Emilia (IT), Tampere (FI), Tartu (EE), and Trikala (EL).

Due to the variety in approach and context in the ten pilot sites, the project can provide guidelines for other cities to replicate the experience and lessons learned. The project analyses the system performance in view of safety and environmental impact, as well as its multimodal integration with the transport network. The individual and public response, as well as socio-economic potential of the services, are also looked at. Ride2Autonomy helps to develop new mobility concepts for passengers leading to healthier, safer, more accessible, sustainable, cost-effective and demand-responsive transport.

The project aims at harmonising research and innovation efforts around automated shuttle solutions by assembling the lessons learned not just from the project's ten pilot sites from ten EU member states, but also from a number of further sites and national networks that have expressed their willingness to exchange their knowledge and lessons learned through their own demonstration projects and activities.

To this end, Ride-to-Autonomy will involve the coordinators of three major shuttle demonstration projects: SHOW, FABULOS and ARTFORUM and their own demonstration sites, to validate two key deliverables: the "Scalable Model" toolbox (D4) and the "Lessons Learnt" guide (D5). This knowledge base, capitalising on much more than the ten project sites and supporting/follower organisations (shuttle suppliers, public transport operators, towns and cities), will duly accelerate the implementation of innovative automated shuttle solutions and services across Europe, thereby exploiting the full benefits of such solutions as part of an integrated sustainable mobility system.

Figure 15: AV-shuttle pilot at the Port of Barcelona (Source: Pendel Mobility, Ride2Autonomy)

Testing new service models with an integrated research agenda for CCAM deployment in Leipzig

Within Dynaxibility4CE, the Leipzig Transport company (LVB) focused on advancing a holistic planning process towards innovative low-carbon mobility through developing a standard portfolio of Demand Responsive Transport (DRT) services integrated with public transport. To this end, it coordinated knowledge exchange and cooperation among key local research initiatives: Flexa, a DRT pilot project; ABSOLUT, aiming for highly automated driving of public transport compatible vehicles; and Netz24, focused on preparations for a fundamental Public Transport network reform, addressing infrastructure rebuild for tram, bus and Flexa services. Contributing to the automated vehicle market is crucial, since today OEMs focus on the private car rather than public transport suitable vehicles.

Contrary, learning things around the DRT service immanent to automated vehicles should not wait until the breakeven of autonomous vehicles. A shift towards sustainable modes of transport is needed now. Testing new service models is key for such objective. Flexa operates already today and LVB together with Leipzig citizens identify challenges and requirements very early in the market. Following up on this effort, the ABSOLUT project is testing AV-Pilot serices, in close cooperation with public transport operators as prime integrators of such CCAM fleets. This considering that they have local knowledge to prepare and identify operational fields, are on site and can resolve conflicts physically, already operate control rooms, and, most importantly, via tele-operated driving they can benefit from incremental improvements in technology reducing the number of human interventions increasing the number of tele-operated vehicles per teleoperator. This can reduce costs even before the breakthrough of real autonomous driving.

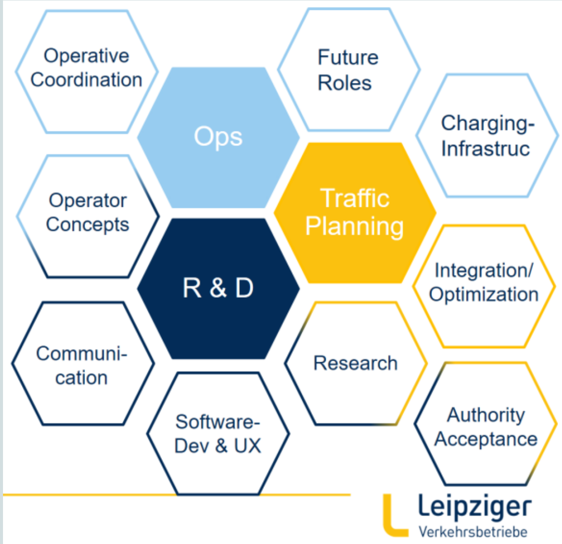


Figure 16:

However, the challenge from pursuing goals towards a shared goal from different sides is the synchronization and regular exchange between both paths. Since both parts are more and more merging this synchronization will become more and more crucial.

To this end, integrated planning with regular meetings and an organizational overlap is essential, as well as capacity building efforts and effective stakeholder engagement. For the political mandate it was necessary to engage with the administration, with the public and with representatives on the neighbourhood and city level. During stakeholder analysis LVB learned about other citizen engagement initiated from the City Planning Department. This process matched their spatial and temporal scope for engagement, enabling synergic cooperation. The DRT engagement benefitted from the established engagement format and the coordination between city of Leipzig and transport company.

Beyond the local political mandate, a license for the operation of transport service is mandatory. A lot of exchange on vision and details in operation was necessary with the licensing authority to satisfy the requirements originating from classical line-based transport services. In Germany in 2021, the law on transport services was renewed and received a concrete article for PT-based DRT services. This involved a change of the responsible licensing authority. Exchange with others DRT providers and transport companies supported us to suggest lean and appropriate recommendations for the licensing procedure.

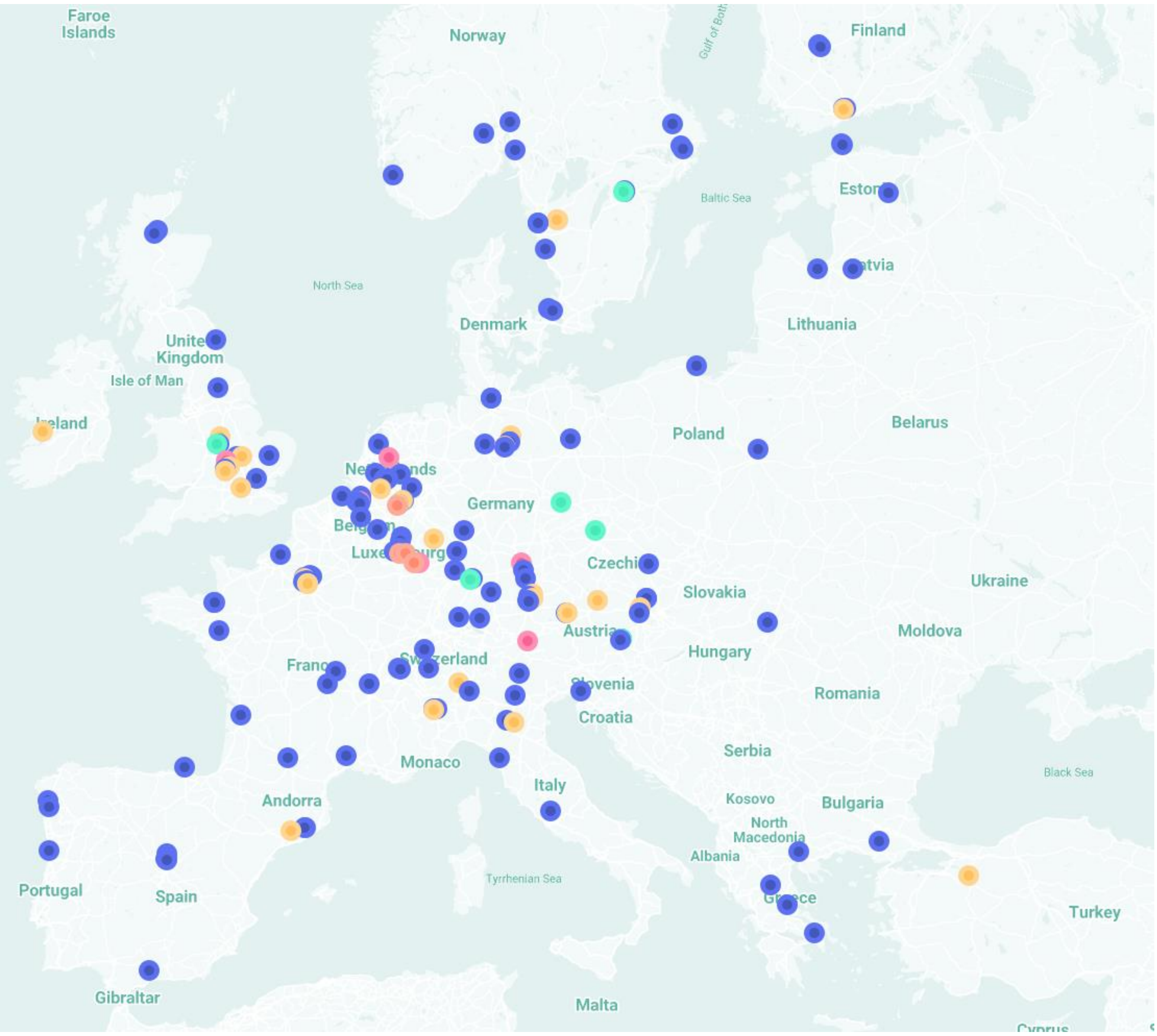


Figure 17: (connectedautomateddriving.eu/test-sites)

3.3.4. Policy and regulatory measures

Authorities need to develop new regulatory frameworks to lead the transition to the new mobility era of sustainable and interconnected mobility with CAVs. New policies need to be adaptive and anticipatory, and based on a balanced governance. These could include pricing of empty runs, occupancy-based pricing of services, etc. Authorities need to (re)assess and monitor the necessary characteristics and requirements of regulatory schemes and policies to accommodate new CCAM services while meeting cities' economic, political and social ambitions These policies will highly depend on the technological maturity in the next 15-20 years (or even more) and also on the economic conditions of the city and country, and their data management policies. The ongoing H2020 project GECKO investigates these challenges. For more information, visit: h2020-gecko.eu (GECKO, 2019).

3.3.5. Advanced Networks and Traffic Management

Transport infrastructure, vehicle technology and mobility digitalisation are progressively improving, while the movement of people and transport of goods is continuously increasing. European transport systems still face major challenges in terms of safety, greenhouse gas emissions, traffic congestion and its derived costs. To solve these issues, connected intelligent transport systems and infrastructure are being deployed, namely more efficient multimodal transport (e.g., new business models, improved safety and efficiency and enhanced customer experience).

However, these new systems come with challenges. Despite high transport data availability, the services provision granularity is generally low and data formats' heterogeneity high especially when different stakeholders and transport modes are involved. The exchange of information, cooperation, and synchronization remain insufficient. As a result, there is a lack of coordination between supply and demand from a multimodal perspective and the efficiency of the overall transport system is not optimised. Improvements in the resilience of the overall transport network to foreseen and unforeseen events/disruptions affecting transport infrastructure and operations are essential.

Cooperative network and traffic management

TANGENT overall objective is to develop new complementary tools for optimising traffic operations in a coordinated and dynamic way from a multimodal perspective and considering automated/non-automated vehicles, passengers, and freight transport. TANGENT supports the knowledge and management of mobility flows among transport modes in addition to enabling the implementation and integration of innovative mobility solutions, services, and business models.

TANGENT focuses on different transport modes, systems for synchronising and optimizing overall transport networks. As a result, it will deliver new models and techniques to support efficient traffic operations in multimodal transport networks in a dynamic and adaptive way. This is implemented through several steps:

Data from intermodal mobility will be captured both by sensors deployed to monitor the activity of the transport network (trains, road traffic, ferries…), as well as data generated by users and vehicles. The data will be used to determine the traffic conditions of urban sections and deliver warning and recommendation services based on vehicle to user (V2X) communication. Travel behaviour modelling is devoted to the understanding and modelling of the travel behaviour of transport users. It will include dynamic mechanisms to replicate users' decisions in the presence of unexpected events and system disruptions.

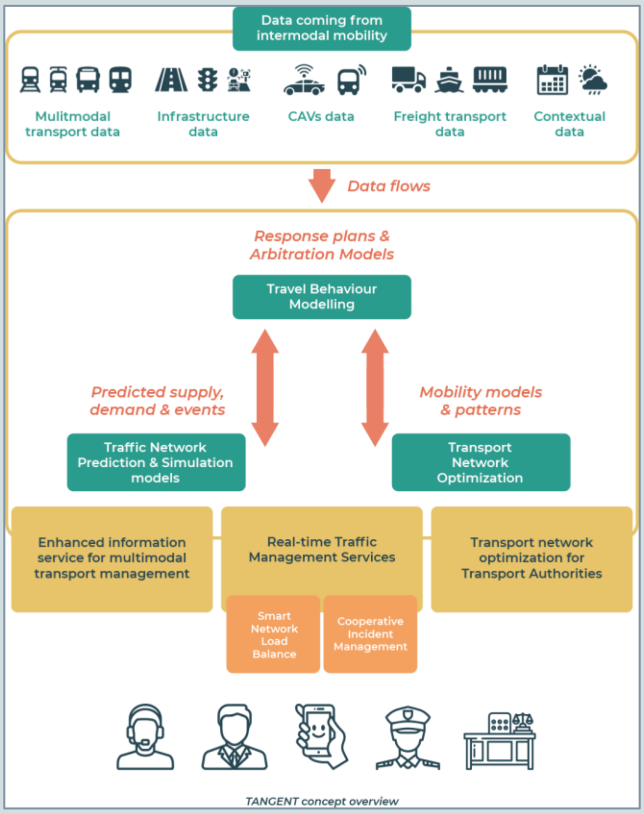


Figure 18: TANGENT concept overview (TANGENT)

3.4. Phase 4 – Implementation and monitoring

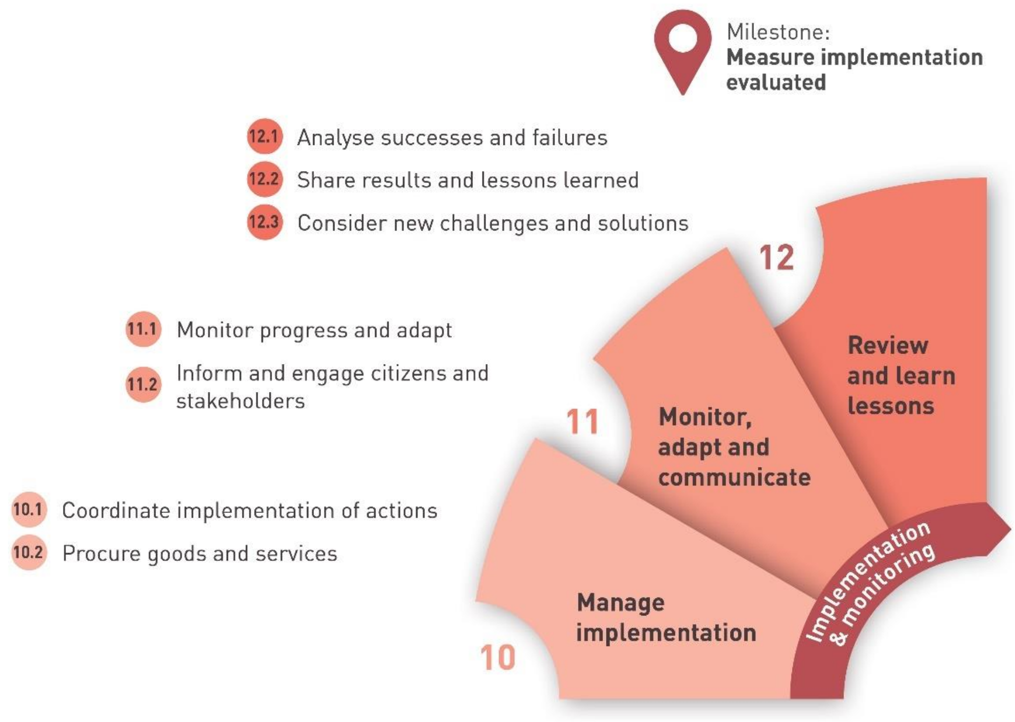


Figure 19: SUMP-Phase 4 (Rupprecht-Consult, 2019)

At this stage of the SUMP process, the implementation of resultant strategies and measures is planned and coordinated in detail. The innovative character of CCAM-related actions, and their inherent degree of uncertainty, result in a complex implementation process which may not be any longer performed by the 'SUMP team', but by technical departments with a mostly quite specialised focus; therefore, the overall coordination of the implementation process requires particular attention.

Moreover, continuous monitoring, evaluation and reflection is especially relevant, when taking measures to handle automation in urban transport, as strategies might require adjustments in response to new developments in the field, and results from current implementation will help reduce uncertainties and guide future actions. Such a monitoring concept will allow to determine whether things are not going according to plan – and take corrective actions if necessary. Active participation is absolutely key at this stage, since implementing of innovative mobility schemes can be a great disruption (as well as a great benefit) for the daily travellers. Understanding public opinion, based on an active two-way dialogue, is crucial for a successful implementation process.

3.4.1. Impact assessment methodologies and tools

The capability of making structured and informed decisions about the comprehensive deployment of CCAM in a mixed road environment, requires a high-level understanding of the impacts different deployment scenarios can have on traffic, quality of life and stakeholders involved in local transport planning. It also commands institutional capacity to plan for a future with CCAM by using tools that accurately represent CAV-behaviour in order to identify the impacts of different deployment scenarios.

But, how can we get reliable evaluation results of socio-economic and sustainability impacts of CCAM? Given that an ex ante evaluation is required, how can we build and assess realistic future scenarios for the evaluation? The availability of accurate modelling tools, as seen in the previous section, is thus a key pre-requisite for such impact assessment.

Similarly, identifying key performance indicators to measure the impact of CAVs in urban mobility, is a vital step in evaluating the suitability of different implementation scenarios. In this regard, the EU Horizon 2020 project LEVITATE aimed to provide valuable input, covering the impact assessment cycle from methodology to analysis and evaluation, including guidance for the implementation (For more information, see https://levitate-project.eu/).

Among the different impact assessment approaches that are being currently tested, CoEXist is evaluating the 'automation-readiness' of urban road infrastructure in eight use cases implemented in its four partner cities: Gothenburg, Helmond, Milton Keynes and Stuttgart. To determine whether the studied infrastructure allows the coexistence of automated vehicles, conventional vehicles and non-motorized road users, the project is evaluating whether it can handle an introduction of automated vehicles without significant decline in traffic performance, space efficiency or traffic safety (CoEXist, 2018).

3.4.2. Lessons learned and knowledge exchange

The European Union has strongly supported collaborative research contributing to automated driving, by funding numerous projects in the areas of: Networking, Coordination & Support, Infrastructure, Connectivity and Cooperative Systems, Driver Assistance Systems and Partial Automation and Highly Automated Road Transport. Figure present an overview these projects (ERTRAC, 2022).

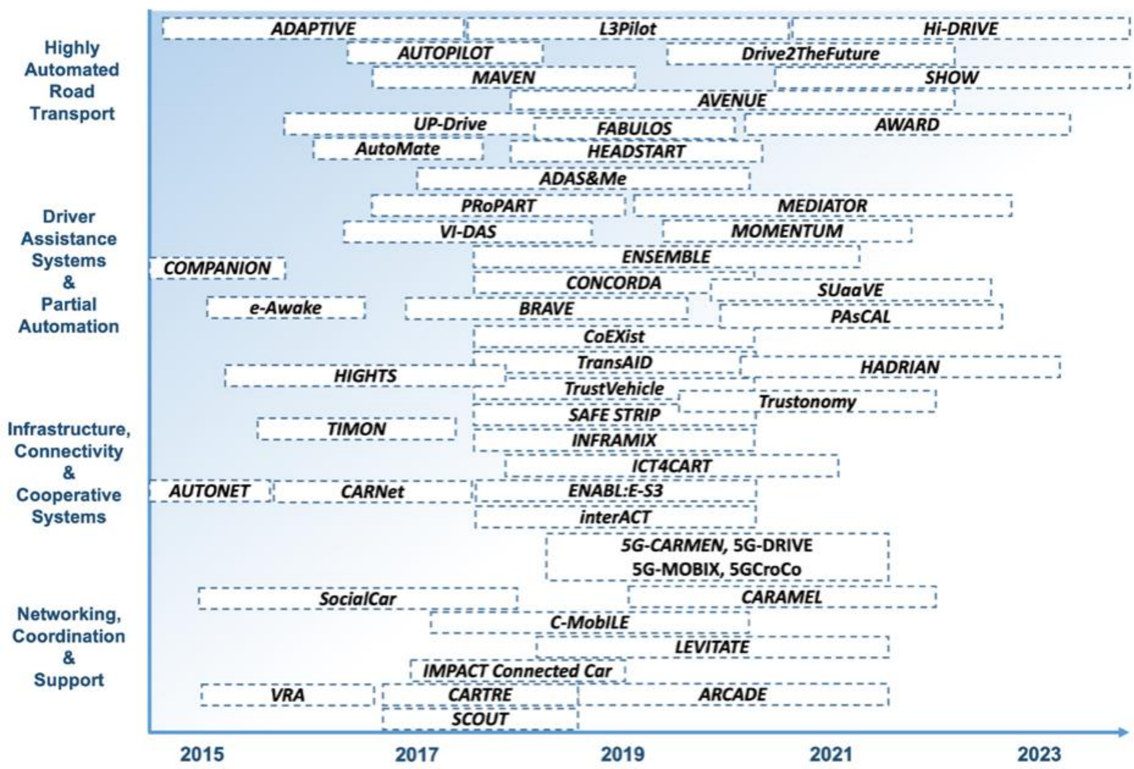


Figure 20: Overview of a subset of EU funded projects that support development of automated driving (ERTRAC, 2022)

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