Enabling “Automation-Ready” Transport Planning

How to become an Automation-Ready road authority?

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Editorial

In some areas, the development of cooperative, connected and automated mobility (CCAM) is progressing fast, fuelled by the promise to reduce congestion, improving safety and mobility for all. Many public authorities and citizens, however, question whether those promises can be fulfilled, and are anxious of the risk of rather amplifying the mobility problems that cities are already facing, which could materialise without proper preparation and planning, and without a proactive approach by cities. The first step to support local authorities in that regard was the dedicated European guidance on road vehicle automation in sustainable urban mobility planning of 2019[1].

The CoEXist project played a major role in its development. This guidance is now supplemented by the deliverables of the project itself that should further allow cities to take more informed decisions when it comes to planning and deployment of CCAM. CoEXist has developed great tools for capacity building around modelling, impact assessment and planning of CCAM scenarios for cities – you will find them in this publication. CoExist outcomes will also feed into building a European Strategic Research Agenda in the field of CCAM to which the EU is strongly associating cities.

[1] https://www.eltis.org/sites/default/files/road_vehicle_automation_in_sustainable_urban_mobility_planning_0.pdf

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After three years of intense work, the CoEXist consortium is glad to present its final results and conclusions. We are confident that they will provide a valuable contribution to start planning for cooperative, connected and automated mobility (CCAM).

The project has developed modelling functionalities to include different types of Connected Automated Vehicles (CAVs), including a comprehensive description of their potential behaviours (e.g., driving logics and default behavioural parameters). Project partners also developed road infrastructure impact assessment tools to adequately interpret modelling results. CoEXist's partner cities, Helmond (NL), Milton Keynes (UK), Gothenburg (SE) and Stuttgart (DE), tested these tools in several use cases, assessing the impacts of CCAM on key aspects of urban mobility: traffic performance, space efficiency and safety.

Results of these evaluations provided evidence for the opportunities of automation as well as for risks of a potential deterioration of urban mobility, especially at the initial stages of CAV deployment. These findings highlight the importance of proactive action from authorities to plan for this transition phase, and the need for further research and policy development.

Finally, CoEXist has developed an automation-ready framework, supporting local authorities in reducing uncertainties and building up their capacity to make structured decisions about CAV deployment.

We hope that our project results will help urban mobility stakeholders to start a more informed planning process for CCAM scenarios.

On behalf of all project partners,

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What is CoEXist?

Programme: EU H2020-ART05 **Duration: May 2017 – April 2020**

Strategic Aim:

Bridging the gap between automated vehicles (AVs) technology and transportation and infrastructure planning, by strengthening the capacities of urban road authorities and cities to plan for the effective deployment of AVs

Enabling mobility planning towards “automation-readiness”, defined as:
The capability of making structured and informed decisions about the deployment of Connected and Automated Vehicles.

CoEXist’s approach

Automation-ready transport and infrastructure planning in cities are a key precondition for fulfilling the promises of connected and automated vehicles (CAVs) to reduce road space demand and improve traffic efficiency and safety. CoEXist is addressing three key steps in transport and infrastructure planning:

Automation-Ready Transport Modelling

Validated extension of existing microscopic traffic flow simulation and macroscopic transport modelling tools to include different types of CAVs (passenger cars/light-freight vehicles with different automation levels).

Automation-Ready Road Infrastructure

Develop tools to assess the impact of automated vehicles on traffic efficiency, space demand and safety, and provide guidance on infrastructure development, to suit both conventional and automated vehicles.

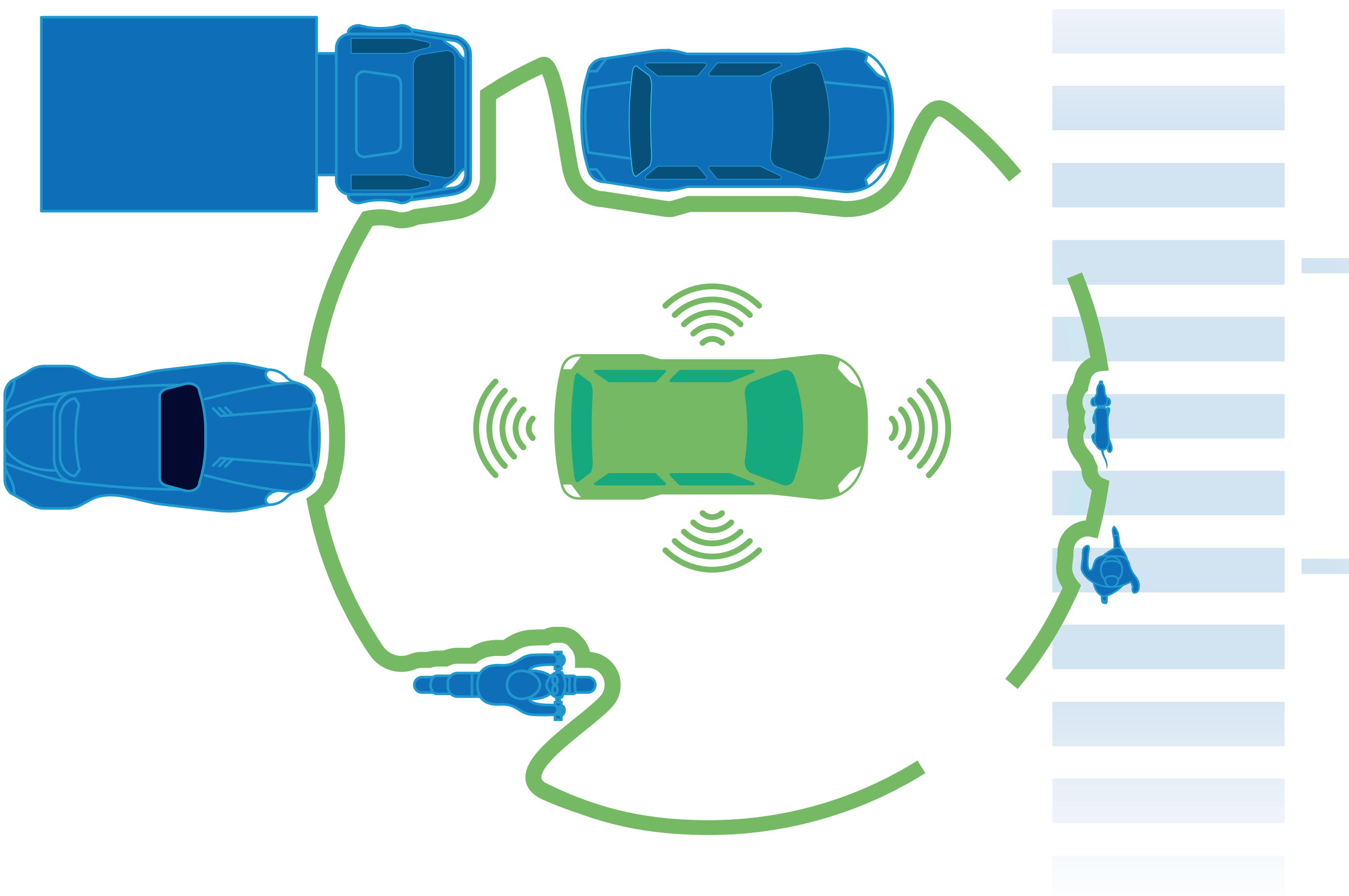
Automation-Ready Road Authorities

Elaboration of eight use cases in four local authorities (Gothenburg, Helmond, Milton Keynes and Stuttgart), used to evaluate – with the CoEXist tools – the impacts of automated vehicles on traffic efficiency, road space requirements and safety, to guide local policy discussion and identify strategies to improve automation-readiness.

Why is CoEXist necessary?

To ensure a positive roll out of CAVs and its alignment with sustainable urban mobility goals, local authorities will have to play a key role and should take the lead with proactive planning approaches. This begins with planning, as early as possible, how the introduction of CAVs should unfold, to 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.

CoEXist provides guidance, tools and methodologies to enable cooperative action and informed decision-making to address the deployment of Cooperative Connected and Automated Mobility (CCAM).



Automation-ready Transport Modelling

Many transport planning decisions affecting urban mobility and road infrastructure are based on the results of traffic flow and transport demand modelling. For this purpose, the availability of adapted simulation software is necessary, including new features and functionalities to allow for more accurate modelling of CAVs.

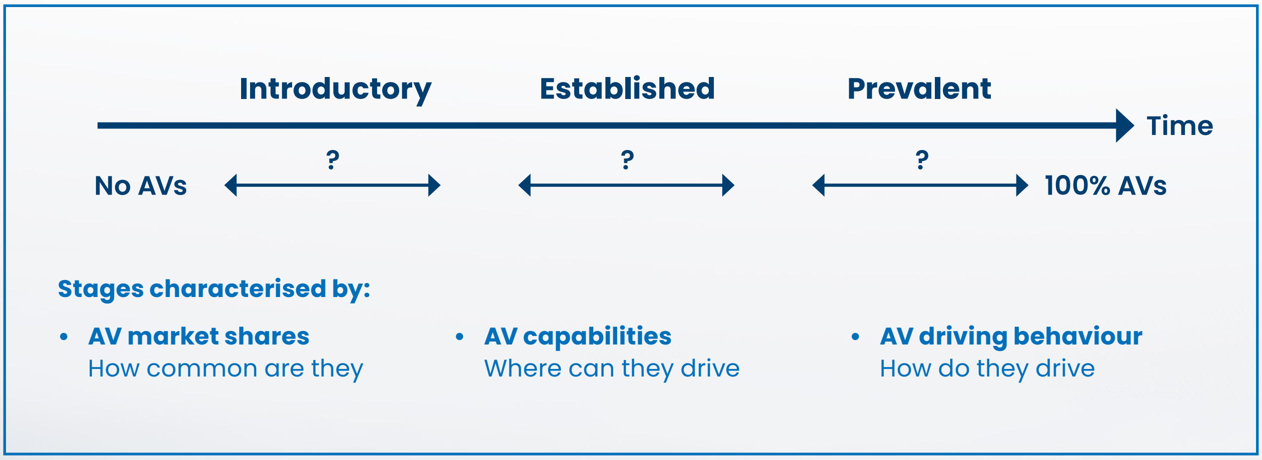
Methodology

Since there are many uncertainties about how future CAVs will behave, CoEXist general modelling approach aims at describing a range of possible behaviours of these vehicles.

The behaviours of the automated vehicles are specified by driving logics which are functionally defined, that is, in terms of how and where they can operate safely, disregarding which technologies make this possible.

Since CAV will likely behave differently in different environments, the driving logics are combined to AV-classes (basic, intermediate or advanced) by determining which driving logic each vehicle should follow , in different road environments.

A goal of the traffic modelling in the CoEXist project is to assess how the impact of automated vehicles on traffic efficiency, space demand and safety, evolves during the whole period of coexistence of conventional vehicles and CAVs, from the first introduction of small number of automated vehicles until when only a few conventional vehicles remain. To enable such assessment the transition period is divided into three stages: introductory, established and prevalent.



CoExist Driving Logics

Rail-Safe

Stops if anything is on collision course. The vehicle follows a pre-defined path for the whole trajectory.

Cautious

Calculates gaps accurately and only merges when gaps are acceptable, and it slows down every time its sensors can have blind angles to have no surprises.

Normal

Behaves as an average driver but with the augmented (or diminished) capacities of the sensors for the perception of the surroundings.

All-Knowing

Perfect perception and prediction of the surroundings and the behaviour of the other road users. It is capable of forcing its way on other drivers whenever is needed without however ever causing accidents.

In this way, the impact of automated vehicles is assessed for each stage with a range of assumptions for the considered variables, to address the uncertainty of the predicted impact. To limit the number of possible combinations, a correlation is assumed between them, considering the vehicles capabilities for each AV-class and the context for each road environment, to determine the applicable driving logics (see an example of the considered mixes in Table 1). Furthermore, the considered uncertainty parameters include the penetration rates of the various AV classes, traffic volumes and traveller behaviour adaptation (e.g., changes in travel time perception or pedestrian interaction with other road users).

Road type	Basic	Intermediate	Advanced
Motorway	Cautious	Normal	All-knowing
Arterial	Cautious	Cautious / Normal	All-knowing
Urban street	Manual	Cautious	Normal
Shared space	Manual	Rail-safe / Human	Cautious

Table 1: Example relation between AV-class, driving logics and road environment

Automation-ready microscopic traffic modelling tools

Within the H2020 CoEXist project, significant progress has been made on the macro- and microscopic simulation capabilities to model CAVs and their interactions with conventional vehicles and other road users.

The microscopic traffic flow simulator PTV Vissim was further developed to enable the simulation of CAV-behaviour, considering the differences in car-following distances, simple communication aspects (V2V and V2I) and acceleration behaviour, among other aspects.

Empirical data collected from real AV's on DICTM test track in Helmond (NL) and co-simulations integrating CAV driving logics (VEDECOM), vehicle dynamics (PreScan) and traffic simulator (PTV Vissim), were used to derive, calibrate and validate behavioural parameters of CAVs.

Figure 2: PTV Vissim Simulation Environment - AV Shuttle Pods example ©PTV Group

What is possible in PTV Vissim?

Automated vehicles can have different automation levels, different automation functions, different sensor equipment, and different driving logics. The modelling technique depends on the scope of information you have about the automated vehicles.

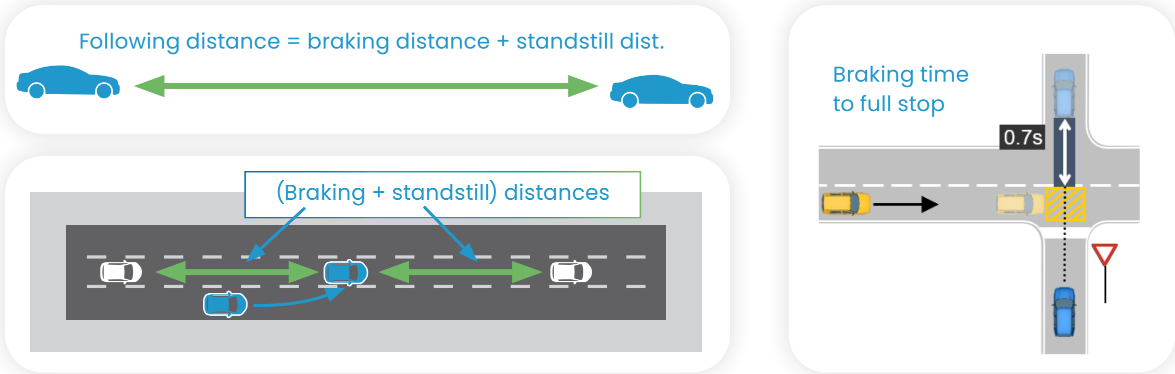


Figure 1: Examples of considered aspects for simulation of CAV-behaviour ©PTV Group

With driving logics algorithms:

If the driving logics algorithms are known or under development, one of PTV Vissim's interfaces can be used to couple the algorithms with the software, allowing direct testing of algorithms, and giving the ability to visualize and compare the interactions between automated vehicles equipped with the algorithms and conventional vehicles provided by the PTV Vissim model. This process is described in 'D2.2 Technical Report on connecting AV control logic and AC Simulator' available on the CoEXist website.

Without driving logics algorithms:

If the algorithms are not known, the driving behaviours offered by PTV Vissim can be used as a starting point for the model. Saying, for instance, automation level 4 is insufficient for microscopic simulation because it requires knowledge or assumptions about the specific behaviour when following lane changing, reacting on signals or resolving conflicts, e.g. gaps, thresholds, etc. Using the human driver as a benchmark, expected behaviour of automated vehicles in terms of desired speed or acceleration can be defined (following headway, its variability, etc.).

Platooning:

Platoons – groups of connected vehicles traveling closely together – are increasingly becoming a factor in traffic planning. Thus, a new feature was developed allowing you to model the effects of platooning on overall traffic.

For more information, see *D2.11 Guide for the simulation of AVs with microscopic modelling tool – Final Version at* https://www.h2020-coexist.eu/resources/

Automation-ready macroscopic travel demand modelling

CAV will influence not only traffic flow but also travel demand. If cars become more comfortable and use the road space more efficiently, car travel demand is likely to increase. Travel demand models replicating interactions between transport supply and travel demand permit estimations how CAV may influence demand.

Starting point are the results of the validated CAV-ready microscopic traffic flow model. They are used to create assumptions for the supply-side of macroscopic travel demand models. Volume-Delay functions are adapted to replicate the impacts of CAV on capacity, which depend on vehicle class, on road type and on the share of CAV. In addition, existing travel demand models can be extended to include changes in the perception of car travel time, as drivers may use some of this time for non-driving activities.

CoEXist's macroscopic modelling tools provide extensions to PTV Visum by adding functionalities to the software in form of Visum compatible scripts, Visum procedure files and Visum Add-Ins. The tools can be integrated into the software to replicate the impacts of CAVs on capacity and demand. They allow the model developer or model user to test various assumptions, extending the capabilities of Visum to enable the consideration of CAVs in travel demand simulations.

Traditional travel demand models apply the four-step algorithm, where trip generation, destination choice, mode choice and route choice are covered to replicate people's behaviour and their movement. Departure time choice may also be considered as a step. Integrating automated vehicles or new mobility services into these models requires additional steps in the procedure, to account for the impacts of AV on supply and demand.

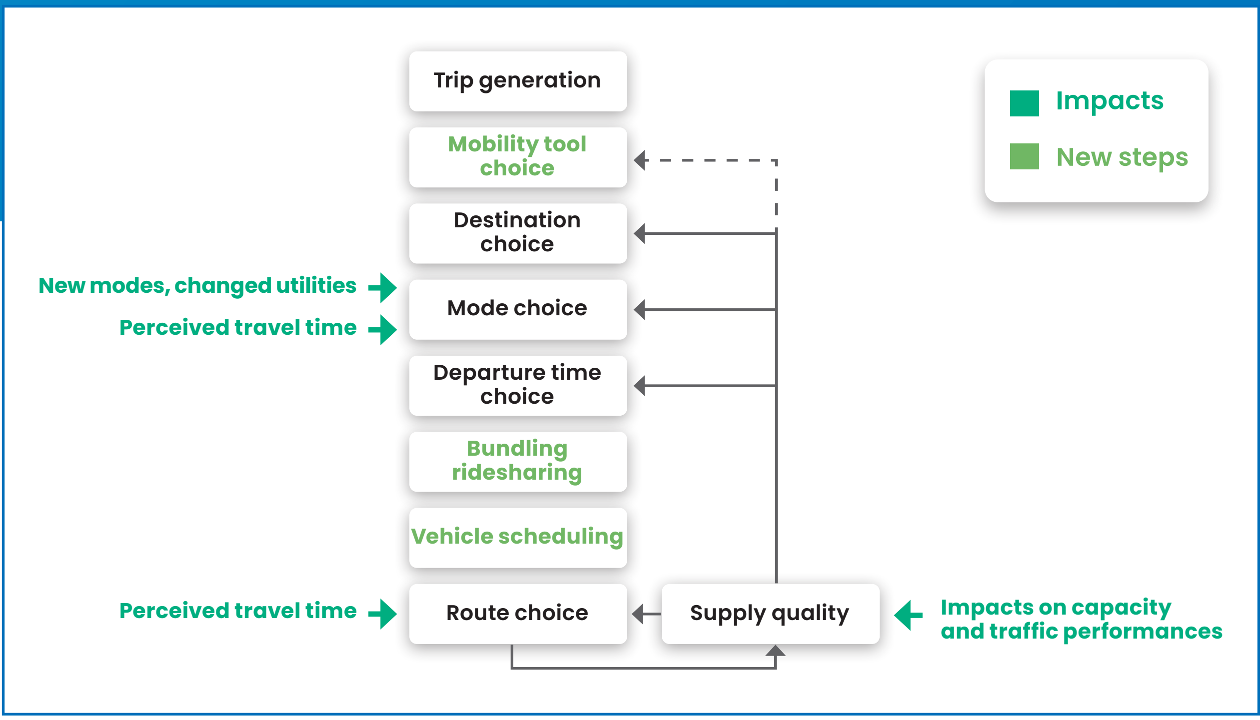


Figure 3: Modelling CAVs with macroscopic travel demand models (©University of Stuttgart)

Volume-Delay Functions:

Traffic assignment methods apply volume-delay functions to describe the relationship between traffic flow, capacity and travel time on each network element. In order to replicate impacts of CAV on capacity, CoEXist's uses the concept of passenger car units (PCU) where capacity and vehicle volumes are converted into passenger car equivalents. Specific PCU values are assigned to CAV depending on the driving logic and road type. The procedure accounts for non-linear effects of different CAV-shares on travel time.

Figure 4: Example of different PCU values per type of vehicle (©University of Stuttgart)

Perception of travel time:

Vehicles that can drive automated on certain road types or network sections permit drivers to use part of the journey for non-driving tasks. As a result, the in-vehicle time is perceived in a different way, affecting the attractiveness of private cars.

Ridematching:

An algorithm is provided which enables pooling trips of suppliers (today typically drivers of conventional vehicles, in the future mobility-as-a-service providers) and demanders (travellers).

Vehicle scheduling:

The model extension computes schedules for fleets of MaaS vehicles while minimizing the fleet size and determining the required empty runs between drop-off and pick-up locations. As result, the model extension provides the required fleet size and the number of empty vehicle trips for a predicted or given demand. Such algorithms already exist for integer demand. However, the developed method is also able to handle non-integer demand, which makes it applicable for macroscopic travel demand models.

For more information, please see *D2.7 AV-ready macroscopic modelling tool, D2.8 Guide for the simulation of AVs with macroscopic modelling tool,* and *D2.9 Built-in functionality for the AV-ready macroscopic modelling tool available.*

Automation-ready road infrastructure

Impact assessment methodology

Automation-ready planning in a mixed road environment, also requires a high-level understanding on the uncertainties and variations of the impacts of CAVs on traffic efficiency, space demand and safety. And consequently its implications to stakeholders involved in local transport planning. Thus, it is essential to enhance institutional capability to plan for a future with CAVs, by using tools that accurately represent CAV behaviour and identify the impacts of different deployment scenarios.

In addition to accurate and robust modelling tools, it is necessary to define relevant indicators to be measured and to develop tools and methods to process modelling results and determine the impacts of CAV deployment on urban mobility and road infrastructure. CoEXist has focused on evaluating the effects of CAVs on: traffic performance, space efficiency and safety.

CoEXist Road Infrastructure Impact Assessment Metrics		
Traffic Performance	**Space efficiency**	**Safety**
• Served Demand Ratio (SDR) • Average travel time (ATT) • Average individual travel time per distance (AITTD) • Average delay (AD) • Vehicle kilometres travelled (VKT) • Person kilometres travelled (PKT) • Vehicle Hours Travelled (VHT) • Person hours travelled (PHT)	• Average Space claim (ASC) • Average space time footprint (STF) • Space time utilisation (STU)	**Qualitative safety assessment approach:** Identification of conflict situations incorporating boundary conditions (such as road environment, road characteristics, type of accident, etc.) which are potentially addressed by each driving function, to qualitatively assess the impacts of automated functionalities on road safety. **Quantitative safety assessment:** through combined simulation and road safety inspections.

Table 2: CoEXist Road Infrastructure Impact Assessment Metrics

For a full definition of the metrics and their calculation methods, please see *D3.2 Definitions of performance metrics and qualitative indicators* at **www.h2020-coexist.eu/resources**

CoEXist's automation-ready road infrastructure assessment tool consists of a set of scripts and spreadsheet-based tool's for the calculation of the above specified metrics and the use case specific impacts on traffic performance and space efficiency based on the micro- and macroscopic simulation outputs, as well as a qualitative estimation of traffic safety effects of different AV-functions for a specific use-case.

For a detailed explanation of the tool's functionalities and guidance for its usage, please see *D3.3 AV-ready hybrid road infrastructure assessment tool*. The scripts and the spreadsheet-based tools are also available for download at **www.h2020-coexist.eu**

Automation-ready road authorities

The overall outcome of the project is to support local authorities on their road towards automation-readiness. Yet the concept of "automation-readiness" should not be misunderstood as an endorsement of the disruptive technologies surrounding CAVs and their impacts, but rather an empowerment of local authorities to critically review the anticipated technological changes and shape the future according to their expectations. Hence, the concept of "automation-readiness" is defined as:

The capability of making structured and informed decisions about the comprehensive deployment of CAVs in a mixed road environment.
This capability requires:

- A clear awareness of the technology underpinning CAVs, the different functional uses and business models for CAVs and a high-level understanding of the impacts different deployment scenarios can have on traffic, quality of life and stakeholders involved in local transport planning.
- The institutional capacity to plan for a future with CAVs by using tools that accurately represent CAV behaviour in order to identify the impacts of different CAV deployment scenarios.
- A strategic approach in setting up a wide range of measures that will ensure a deployment of CAVs, which supports higher level mobility goals.

Demonstation of CoExist tools

Microscopic

Macroscopic

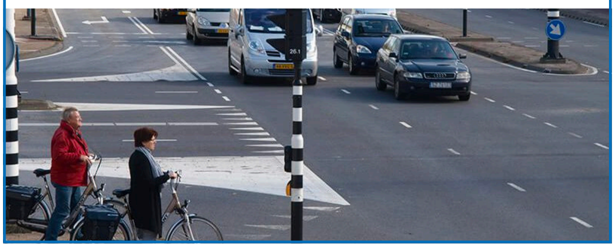
The automation-ready tools developed within the CoEXist project have been used to evaluate the traffic impact of automation for eight strategically selected use cases in four different cities:

Gothenburg, Sweden

- Shared spaces
- Accessibility during long-term construction works

Helmond, the Netherlands

- Signalised intersection including pedestrians and cyclists
- Transition from interurban highway to arterial

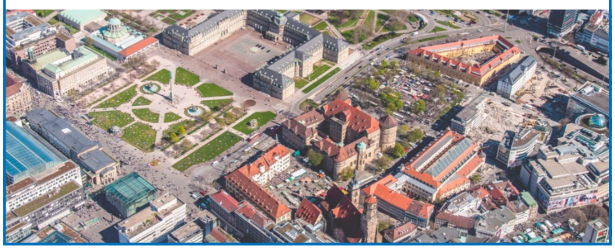


Milton Keynes, United-Kingdom

- Waiting and drop-off areas for passengers
- Priority Junction Operation (roundabouts)

Stuttgart, Germany

- Impacts of CAVs on travel time and mode choice on a network level
- Impact of driverless car- and ridesharing services



Use case 1

Shared space (Gothenburg, SE)

Q Can CAVs get through a lively shared space, packed with pedestrians?

A shared space in the city centre of Gothenburg is modelled with a microsimulation model in Vissim, with the Viswalk addition to better represent the motion of the pedestrians. The evaluated scenario is the introduction of an automated last mile service passing through the shared space to assess how advanced automation technology is required for such a service to be feasible from a traffic performance perspective.

The deployment area is characterised by high flows of pedestrians and public transport (PT), and lower capacity for car traffic expected through CAV introduction, due to possible difficulties concerning the interaction between the vehicles and pedestrians. The addition of zebra crossings for the channelization of pedestrian flow was considered as measure to be tested.

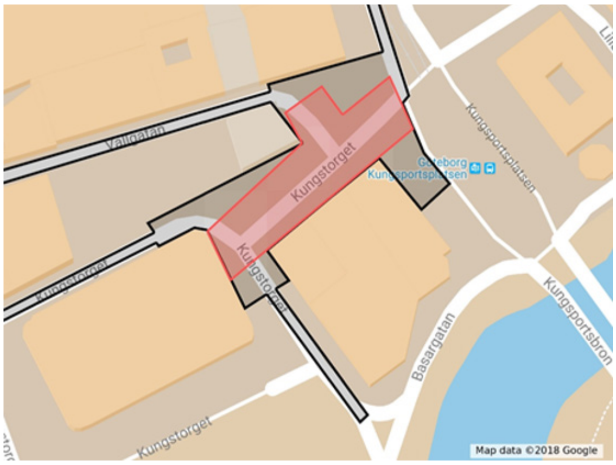


Figure 5: Use case 1 deployment area (©VTI)

Figure 6: Use case 1 illustration (City of Gothenburg)

Overview of main results:

- Negative impacts on conventional vehicles and minibuses on all the investigated traffic performance metrics. Conditions improve more advanced AVs
- AV's will take longer than CVs to cross a shared space, due to the speed limit compliance that is assumed for AV's but also due to their "passiveness" in comparison to a conventional car.
- Pedestrians will hardly experience any difference at all with regards to the traffic performance metrics, as they are always given right of way.
- Although, vehicle traffic performance is negatively affected, vehicle demand is served and there is no breakdown due to interactions between AVs and active modes.
- Considering potential benefits on safety and speed-limit compliance, local policy goals should guide prioritisation of KPI's to determine automation-readiness.
- Measure: Zebra-crossing implementation resulted in breakdown due to high pedestrian flows and compliant AVs.

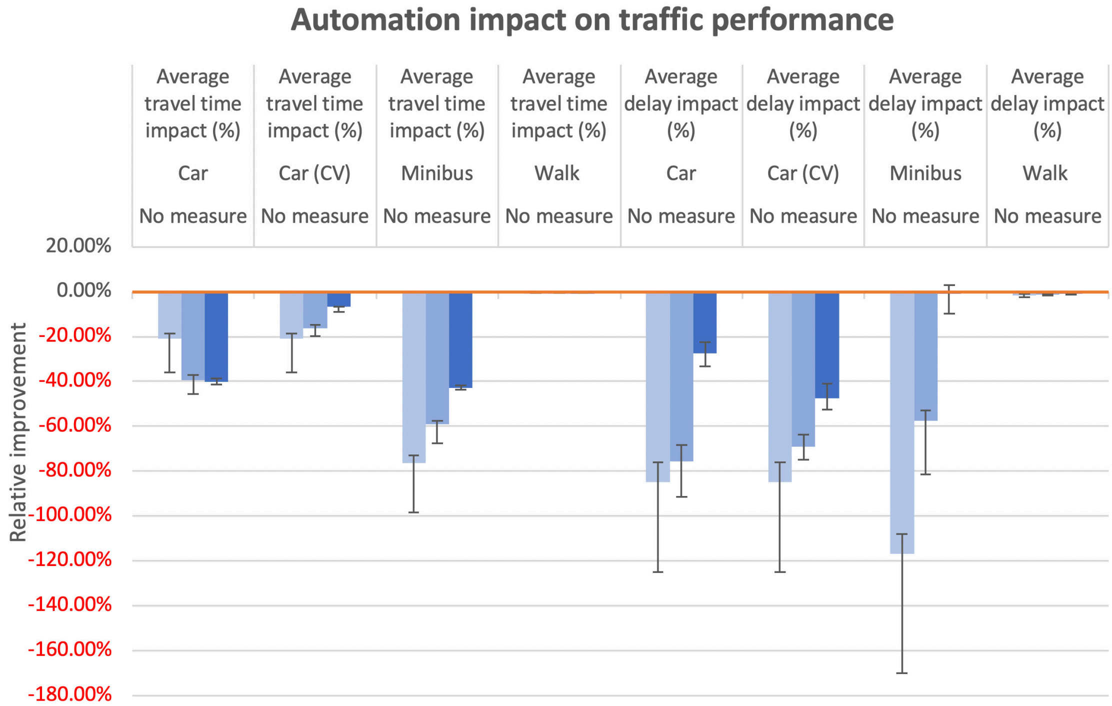


Figure 7: Automation impact on traffic performance in use case 1 (VTI)

Use case 2

Accessibility during long-term construction works (Gothenburg, SE)

Q ***How does the introduction of AVs cope with constant changes of traffic flows during construction works?***

A macroscopic Visum model for Greater Gothenburg has been used to investigate how accessibility during long-term road construction works is affected by the introduction of CAVs.

Long-term construction is a common issue in cities and puts a lot of stress on the traffic system. It is therefore important to ensure that the introduction of AVs does not imply further negative effects and investigate which measures can improve traffic during extended construction periods.

Depending on the CAV penetration rate, bidirectional traffic and other capacity supporting measures in tunnels could be possible. In this sense, two measures have been tested: (1) a two-way AV-only tunnel tube for the Göta Tunnel; and (2) reserved bus and AV lane on the major motorway network.

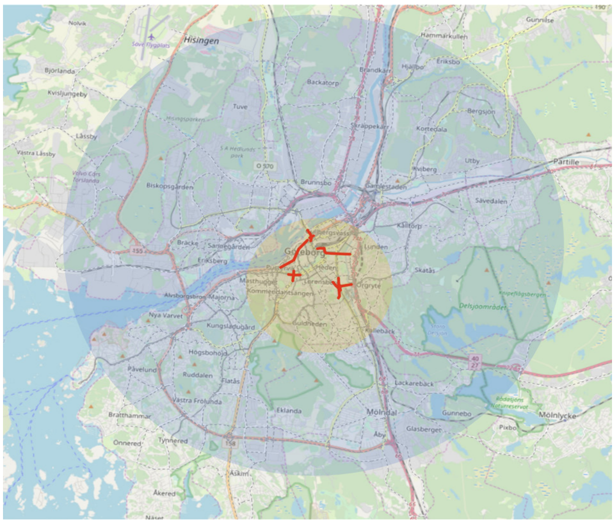


Figure 8: Modelled area in Greater Gothenburg

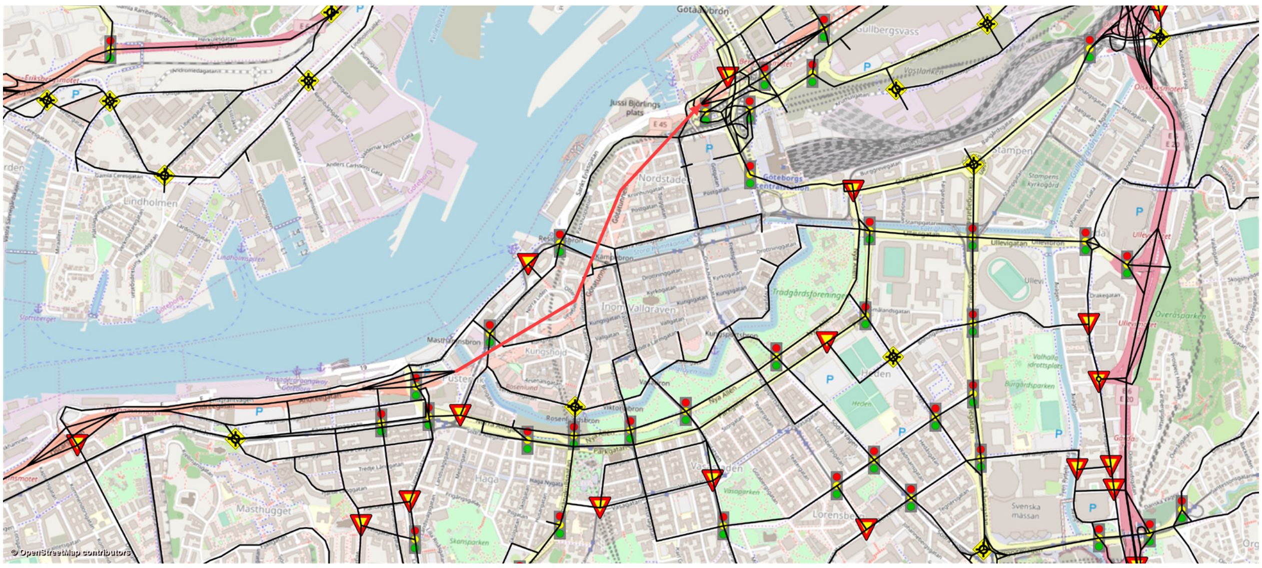


Figure 9: Use case 2 model illustration (VTI)

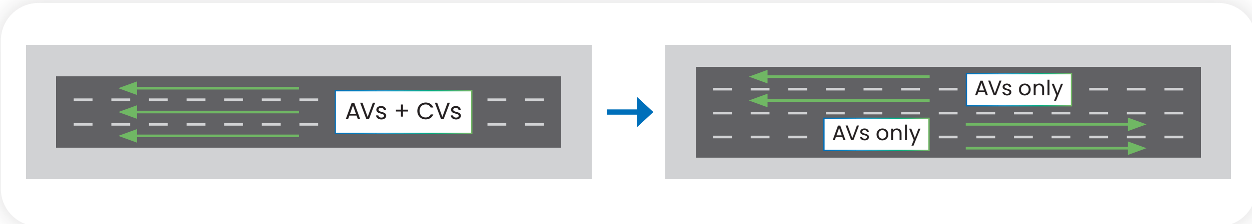


Figure 10: Measure 1 - Two-way AV-only tunnel tube

Overview of main results:

For current infrastructure:

- Transition from marginal increases in travel time and delays at the introductory stage, to considerable decreases at the prevalent stage. Positive impacts are observed as the share of intermediate and advanced AVs rises.

Measure 1: Two-way AV-only tunnel tube

- Marginal increases in travel time and delays at the introductory stage, slight decrease in travel time and delay at the established stage and somewhat larger effects at the prevalent stage. Conventional vehicles also see improved traffic performance due to shift of AVs from alternative routes to the tunnel, thus freeing capacity on the network.

Measure 2: Reserved 'Bus + AV' lane on the major motorway network

- Positive results during the introductory stage for bus performance, with marginal increases in travel time and delays for conventional cars. While no effects are seen for either vehicle type in the established and prevalent stages, since the number of AVs increases and so those the use of the prioritised lanes.

Use case 3

Signalised intersection including pedestrians and cyclists (Helmond, NL)

Q ***Is the performance of the intersection getting better because of a more efficient flow thanks to CAVs?***

A microscopic Vissim model is utilized to investigate the impacts of introducing automated vehicles to the traffic at the transition from highway to arterial road with signalised intersections.

Use case 3 focuses on evaluating the impact of CAV deployment, on the performance of a signalised intersection.

Key factors:

- Advanced signal control strategy is represented in Vissim through a connection to an external traffic signal simulator.
- All modes present in the intersection are modelled, assessing the effects on pedestrian and cyclists due to reallocation of traffic signal times.
- The city's strategy 'Mobility Vision 2016-2025' aims to provide a sustainable and safe traffic system, promoting bicycle and smart mobility.

Figure 11: Signalised intersection in Helmond

Overview of main results:

- Travel-time/delays increase for CAVs, in comparison with CV: effects of speed-limit compliance by AVs and decreased saturation flow due to cautious behaviour (at introductory stage), as potential causes.
- Increased travel time for bikes and pedestrian due adaptive signal control which reallocate green times to vehicles – measures required to ensure walk/bike users are not negatively impacted by increased congestion.
- Only for high penetration rates and more advanced CAVs, results are comparable or better than the baseline situation (with no CAVs).

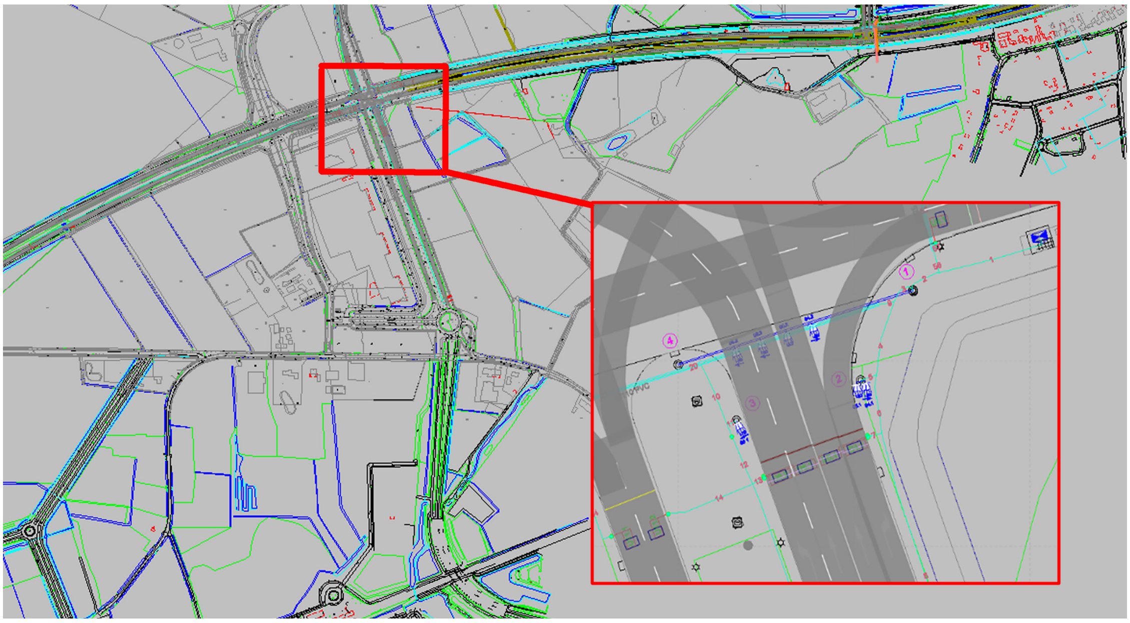


Figure 12: Use case 3 model illustration (Helmond)

Use case 4

Transition from interurban highway to arterial (Helmond, NL)

Q ***Can CAV deployment improve traffic conditions in transitions from highway to arterial roads?***

In complement to use case 3, this use case focuses on investigating highway traffic conditions and the impacts of introducing automated vehicles to the traffic at the transition from highway to arterial road.

The use case site is the road between Eindhoven and Helmond, which changes from an interurban motorway to an urban road, with each having very different speed limits and traffic conditions.

Helmond is very active in researching and evaluating all kinds of projects in the field of CCAM. The city is currently also strongly committed to rolling out Intelligent Speed Adaptation (ISA), considering that CAVs (with ISA applications), could contribute to reducing speeding violations and achieving a more homogeneous speed, that results in more reliable travel times and fewer delays for total traffic.

Cooperation among CAVs as part of a convoy (platoon), constitutes a promising functionality for the optimisation of traffic conditions in these types of roads. To evaluate such impacts, Helmond has tested measures including: (1) enabling the formation of CAV-platoons of up to 8 vehicles; and (2), then, limiting platooning to the right lane only.

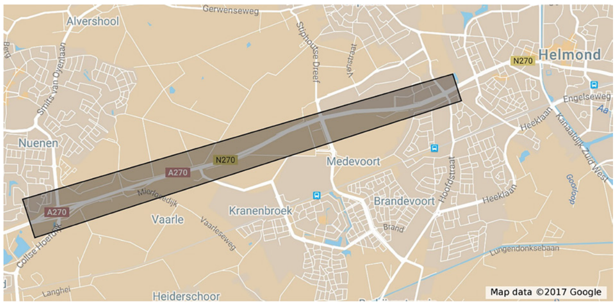


Figure 13: Use case 4 site

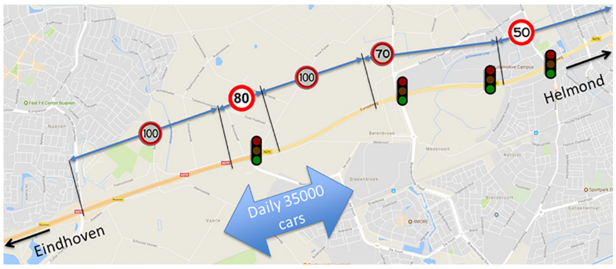


Figure 14: Varying speed limits illustration – use case 4 (Helmond)

Overview of main results:

- Travel time increases for CAVs in comparison to conventional vehicles, given full speed-limit compliance.
- Decreased saturation flow at intersections due to 'Cautious' driving behaviour, and increased saturation flow for All-knowing behaviour.
- Increased travel times due to speed reductions, but decreased delays as CAVs become more advanced.
- Enabling platooning, in both measures, resulted higher saturation flows, and cosequently slightly shorter delays. It shows when penetration rate is rising and CAV's become more sophisticated, positive effects will be reached in traffic performance and space utilisation.

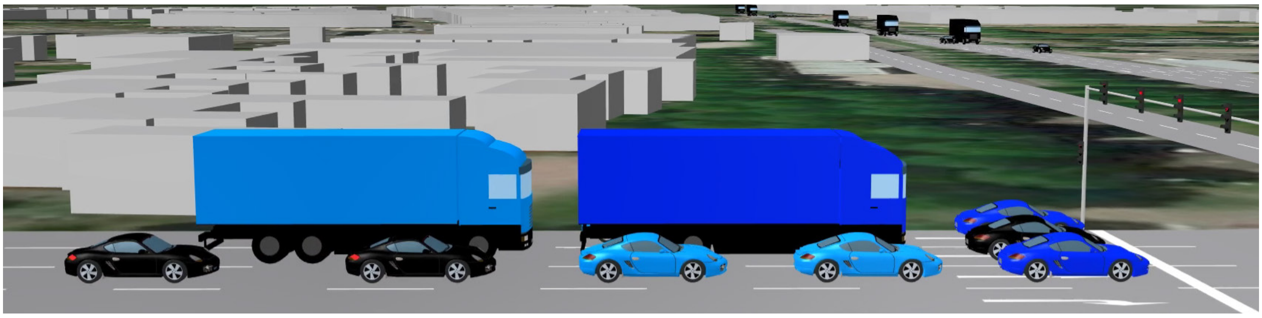


Figure 15: CAV Platooning simulation with PTV Vissim. ©PTV Group

Use case 5

Waiting and drop-off areas for passengers (Milton Keynes, UK)

Q ***What would be the city-wide traffic consequences for Milton Keynes if CAV's become commonplace and the city-centre is re-defined as a car-free space?***

The objective of this study was to explore the impact of widespread CAV take-up combined with a plan to re-define the city-centre as a car-free zone. The objective was to assess traffic flows on the streets surrounding a car free city-centre. The simulation included passenger pick-up and drop-off points which were placed at multiple points around the perimeter of the car free zone.

CAV's obey logical and precise rules of movement and do not respond in a manner which reflects the conventional behaviour of a human driver. Traditional macroscopic modelling techniques could not therefore be used for this study.

For this reason an extensive VISSIM microsimulation model was built and exercised.

Current roads and traffic flows were simulated first to provide a 'reference scenario'. In this model, the city centre was open to all vehicles and the vehicles were given normal non-CAV behaviours. In subsequent models, different pick-up/drop-off configurations were examined alongside different levels of CAV penetration.

This use case:

- evaluated the relative merits of three different approaches to providing pick-up/drop-off facilities for the users of CAV's.
- analysed how the city of Milton Keynes could be best prepared to tackle the widespread future uptake of autonomous vehicles.

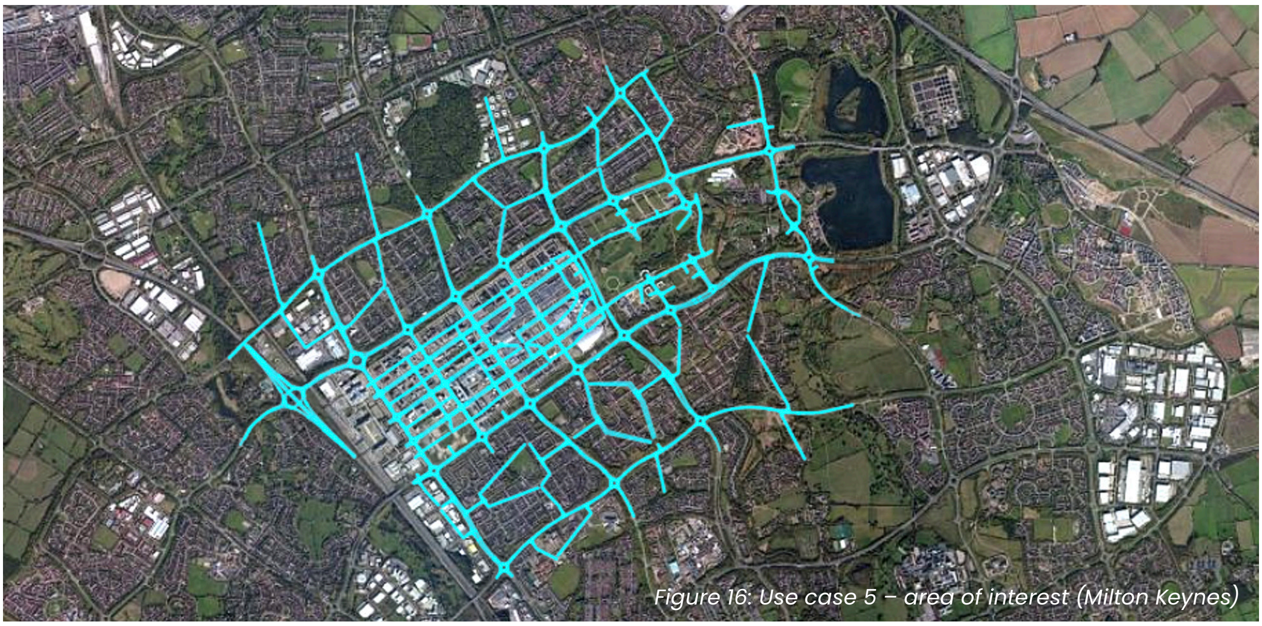


Figure 16: Use case 5 – area of interest (Milton Keynes)

Overview of results:

- In comparison with the initial reference simulation in which only conventional vehicles were included, traffic flow deteriorated and travel times increased when 'first generation' (cautious) CAV's were introduced. This is referred to as the introductory stage of autonomous vehicles in the diagram below.
- The situation improved when 'second generation ('more confident') CAV's were introduced. This is referred to in the diagram as the 'established' stage.
- A significant further improvement occurred when 'third generation' (all knowing) CAV's were introduced. This is referred to in the diagram as the 'prevalent' stage.
- The three stages of CAV penetration were then repeated for three different infrastructure interventions (the 'measures')
- A notable result in all cases is that the benefits of improved traffic flow apply to all vehicles on the road at any time (CAV's and non-CAV's alike).

Measure 1: 'Pick-and-Drop' Areas

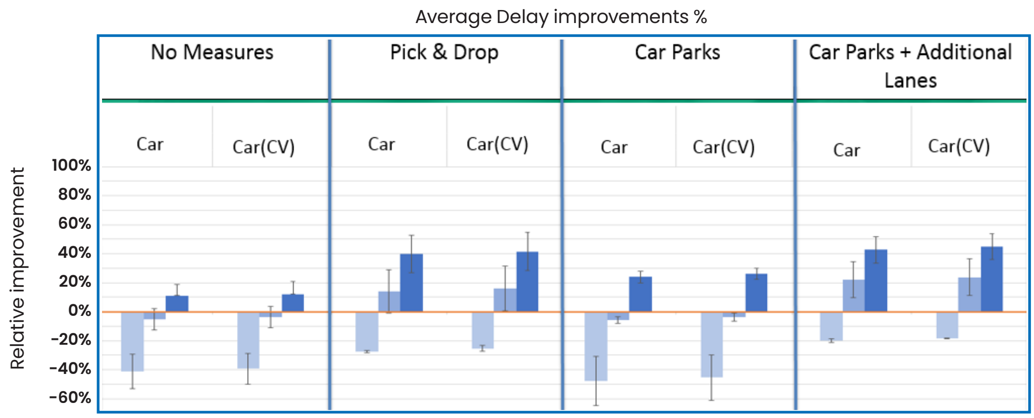
- This measure appears to work well. Whilst the introductory stage leads to an increase in delay times compared to the reference case, the established and prevalent cases yield progressive reductions in journey delay times.
- A 40% reduction in journey delay times is achieved by the time the prevalent stage has been reached.

Measure 2: Multi-Storey Car Parks

- This measure works less well than Measure 1, primarily because of the queues which build up at the car-park entrances and tail-back to the main streets.
- As a result, the introductory stage creates a 50% increase in journey delay times whilst the prevalent stage yields only a 20% reduction in journey delay times.

Measure 3: Multi-Storey Car Parks plus Additional Lanes on Surrounding Roads

- This measure has a significant beneficial effect. It improves the performance of Measure 2, making it comparable to Measure 1 by the time the prevalent stage is reached.



Use case 6

Priority Junction (roundabouts) Operation (Milton Keynes, UK)

Q ***What is the effect on traffic flows at un-signalised intersections (roundabouts) at various different stages of CAV take-up?***

The focus of this use case was to assess traffic performance at the major arterial road intersections in suburban Milton Keynes. Most of these intersections are unsignalized roundabouts.

How vehicles behave at roundabouts is therefore critical to the creation of the general traffic conditions in the city. This makes it an ideal testing ground for how autonomous vehicles might interact within intersection spaces and to evaluate what sort of interventions (measures) might be needed to facilitate the arrival of CAVs.

An initial 'reference' case was simulated in which only conventional vehicles were included in the model. Thereafter, a small number of specific interventions were examined and the results were compared to the reference case.

The interventions (measures) which were examined included:

1. The introduction of V2V communication between vehicles when merging at intersections
2. Introduction of an additional (third) lane in the approach to each intersection.

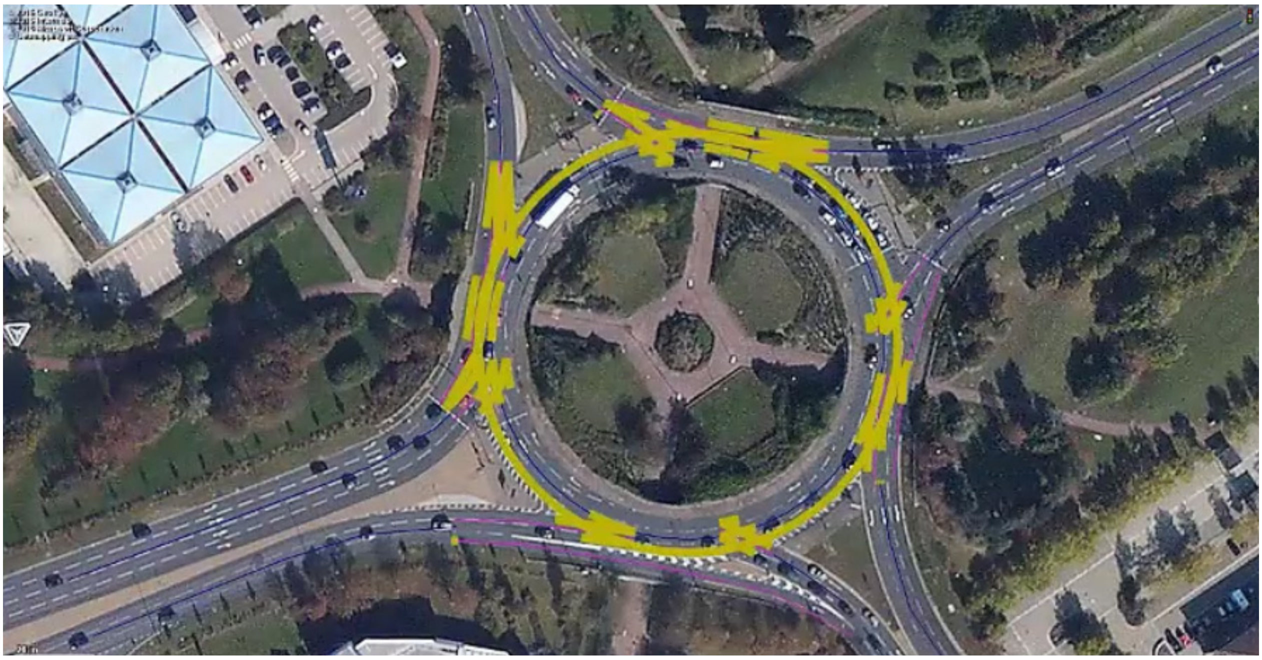


Figure 17: Use case 6 model development process (University of Cambridge)

Overview of results:

- Vehicle movements at the point of entry to the roundabout are highly sensitive to parameters which reflect driver judgement (gaps, opportunities, timing, etc). First generation CAV's, being 'cautious' by design, cause deterioration in traffic flow.
- Even small numbers of 'cautious' CAV's cause significant problems during the 'introductory phase'.
- Second and third generation CAV's are expected to be more capable in their behaviour. For the 'Prevalent' stage, average travel times show an improvement of around 30% when compared to the reference (conventional vehicle) case.
- Human driven vehicles (CVs) see benefits which are similar to those experienced by CAV's. This is because of the orderly traffic flows which prevail when significant numbers of CAV's are on the road.

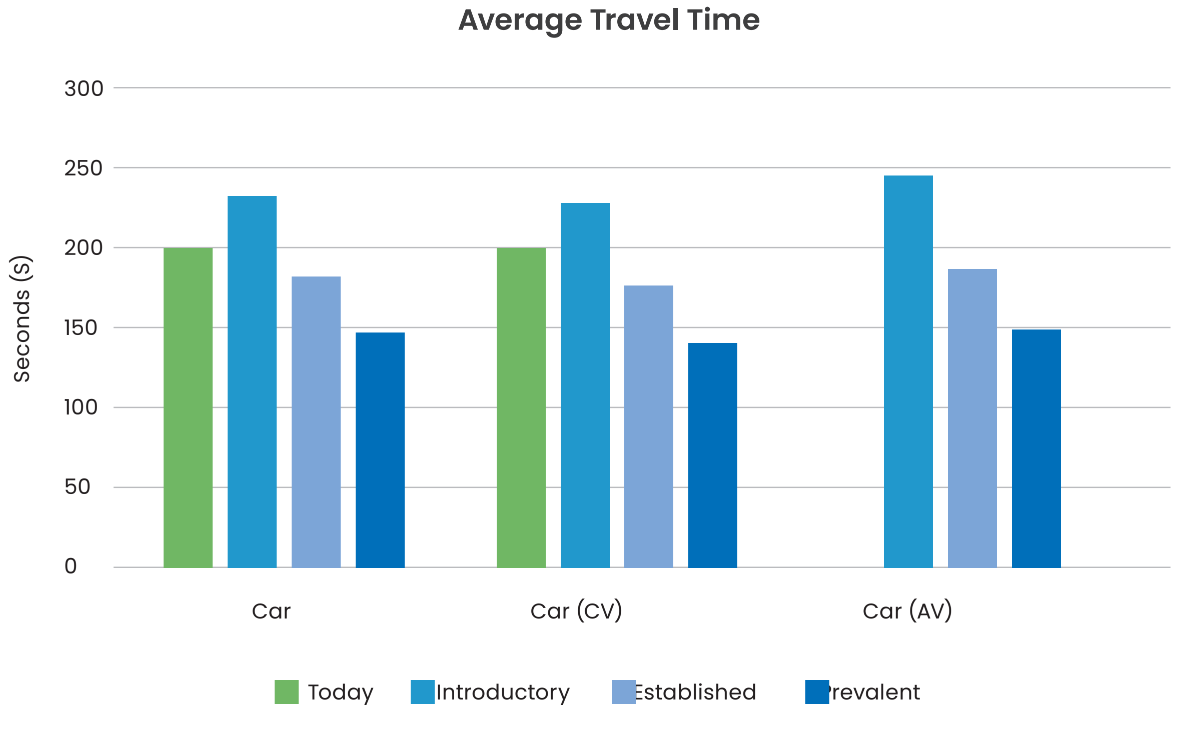


Figure 18: Average travel time

Use case 7

Impacts of CAV on travel time and mode choice on a network level (Stuttgart, DE)

Q

What changes can be expected on motorways, on urban arterials and on urban roads with mixed traffic?

What impacts can be expected on road capacity, congestion levels and travel times?

Use case 7 looks at the effects of automated vehicles on travel time, mode choice and route choice, resulting from changes in traffic performance and changes in comfort of car usage. An extended version of the existing travel demand model of the Stuttgart Region is used to examine the impacts of highly, but not fully automated vehicles.

The use case examines the effects of the following variables on travel demand:

CAV stage:

The stages introductory, established and prevalent vary the characteristics of CAV. In the introductory stage, the driving logic of CAV leads to careful driving which reduces road capacity. In the established stage CAV outperform conventional vehicles on motorways and arterial roads, where cars and non-motorized modes are separated. The prevalent stage assumes that CAV can even operate efficiently on urban streets.

CAV-Share:

The share varies between 0% and 100%

Network:

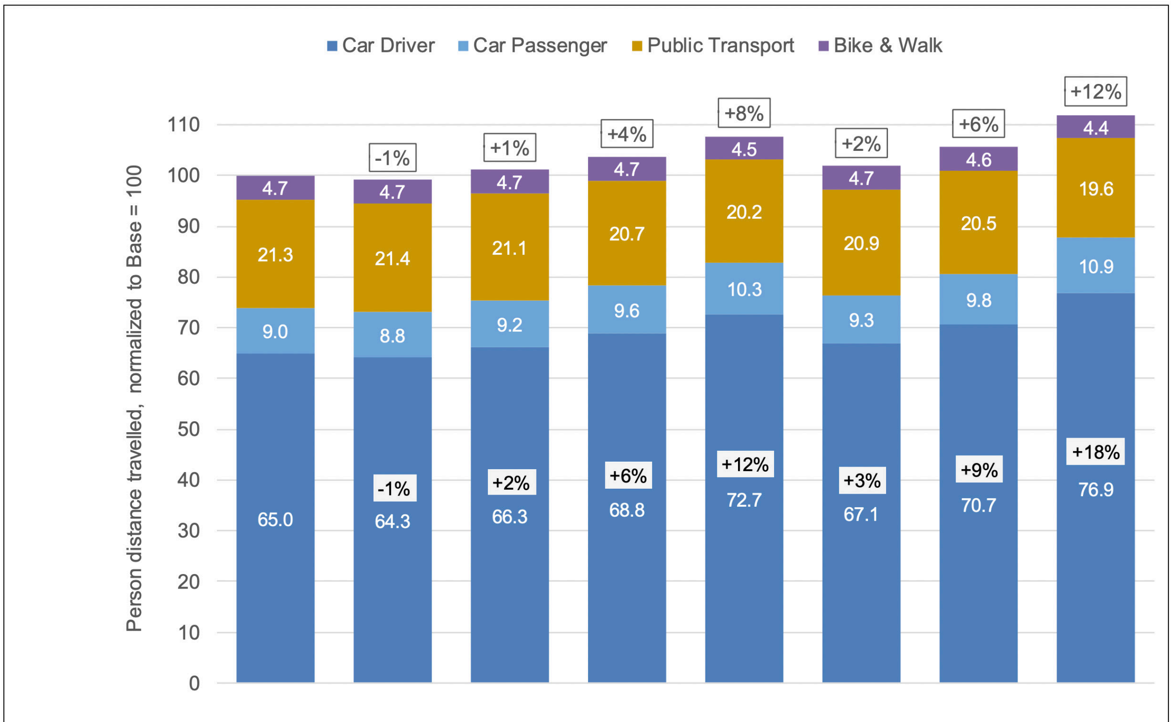
Two cases are distinguished. The case "motorway" assumes that CAV can operate automated only on motorways or on roads with a similar characteristic. The case "main road" additionally includes main roads as CAV-ready roads.

Perception of travel time:

Drivers of CAV may use some of the in-vehicle time for non-driving tasks. This can reduce the perception of the actual travel time. Perception factors of +/-0%, -15% and -30% of CAV travel time are considered, to account for changes in travel time perception.

Combination of variables are used to examine 60 scenarios. Running the travel demand calculation each scenario produces values for a set of indicators:

- number of trips by mode
- total distance travelled by mode
- total time spent by mode



Stage	Base	Intro	Established			Prevalent		
CAV-share	0%	40%	60%			80%		
Network: Motorway Main roads	☒ ☐	☒ ☐	☒ ☐	☒ ☐	☒ ☒	☒ ☐	☒ ☐	☒ ☒
Perception	+/-0%	+/-0%	+/-0%	-30%	-30%	+/-0%	-30%	-30%

Figure 19: Use case 7 – Overview of results for Person distanced travelled (University of Stuttgart)

Use case 8

Impact of driverless car- and ridesharing services (Stuttgart, DE)

Q ***What impact will the introduction of car- or ridesharing services have on modal split and traffic volumes?***

The aim of use case 8 is to examine the impacts of automated car- and ridesharing services on demand. The basic assumption is to have 100% CAV capable of operating completely automated (and therefore driverless) within the Stuttgart Region.

The examined scenarios vary the characteristics of the supply and assumptions on the behaviour:

Supply characteristics:

Case 0 corresponds to the baseline scenario. Cases 1-3 each cover one additional mode with sharing vehicles on top of the traditional modes available in the base case. Case 4 investigates the impact of on-demand services integrated into public transport under the assumption of omitting bus service completely. Carsharing as a competitive mode added to the case 4 is covered by case 5.

Prices:

Prices for shared vehicles (CS, RS-) consist of a fixed booking price and a distance-based price. Integrated ridesharing (RS+) is included in the public transport ticket.

Car ownership:

Car ownership is an input variable to the model. In some scenarios, car ownership is reduced assuming that persons are willing to share vehicles or rides.

Case	Public Transport			Car Transport		
	Bus	Rail	Ridesharing RS+	No-Sharing NS	Carsharing CS	Ridesharing RS-
0	Yes	Yes	No	Yes	No	No
1	Yes	Yes	No	Yes	No	Yes
2	Yes	Yes	No	Yes	Yes	No
3	Yes	Yes	Yes	Yes	No	No
4	No	Yes	Yes	Yes	No	No
5	No	Yes	Yes	Yes	Yes	No

Mode	Properties
Bus	Buses operate as in the baseline scenario, no specific assumptions on automation.
Rail	Light and heavy rail operate as in the baseline scenario, no specific assumptions on automation.
RS+	Ridesharing integrated into public transport. This can come in the form of a last mile service or as direct service in areas with low demand (bus on demand). The system operates with one vehicle size (6 seats). Passengers must transfer to bus/rail, if this provides a reasonable service. Travel time depends on road saturation.
NS	No sharing, cars are privately owned. No specific assumptions on automation. Travel time depends on road saturation.
CS	Carsharing, travel time depends on road saturation. This supply is equivalent to a personal on demand service.
RS-	Ridesharing not integrated in public transport. Travellers always travel without transfers. The system operates with one vehicle size (6 seats). Travel time depends on road saturation.

Overview of results:

- The modal shift from public transport to independent ridesharing (RS-) or carsharing (CS) depends on the prices of the services and on car ownership levels. Assuming that the out-off-pocket costs for these services are approximately 50% higher than public transport and that car ownership remains at current levels, independent sharing services will attract a relatively small amount of all trips (around 2.5%).
- Ridesharing integrated into public transport (RS+) can operate as a feeder service for traditional public transport and offers direct trips where public transport service quality is insufficient. Direct RS+ services provided at the cost of public transport gain a large modal trip share of around 25%. This leads to a total public transport share of 33% (baseline: 14%) and a reduced share for car modes of 41% (baseline: 54%).
- Assumptions on the willingness of people to give up their private vehicle and to share vehicle have a high impact on vehicle traffic. If half of the persons with access to a car give up car ownership, vehicle distance travelled will go down by approximately one quarter.
- As ridesharing eliminates parking costs demand with ridesharing vehicles will increase more in urban areas with paid parking.
- The number of required vehicles can be reduced, if ridesharing integrated into public transport (RS+) and carsharing is available. In this case, up to 25% of all vehicles can be omitted. This number can be further reduced with an increasing willingness to share.

Automation-ready Fora: local cooperative planning and policy discussions

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. Consequently, CoEXist's cities have hosted 'Automation-ready Fora' to engage with local stakeholders, citizens and institutions, based on the 'Automation-ready framework'.

Aiming to facilitate a more informed discussion about the city's vision for automated mobility, each CoEXist city has strategically chosen the scope and target audience of its forum to adjust to its local activities and priorities:

Figure 20: Automation-ready Forum in Gothenburg


Figure 21: Automation-ready Forum in Stuttgart

Gothenburg

The main objective of the forum was to raise awareness of CAVs amongst stakeholders such as national, regional and local authorities as well as other urban mobility stakeholders. A full seminar day on the topic of societal development and automated transports was jointly organised by CoExist and Drive Sweden. One of the core questions raised at the seminar was: how can cities plan for a future where CAVs constitute a natural and integrated part of the urban transport system?

Stuttgart

Cross-sector institutional cooperation approach, engaging with members of its Mobility Working Group (AG Mobilität) which includes representatives from different organisational units of the city's administration, as well as representatives of the local public transport (SSB). Stuttgart analysed the opportunities, challenges and risks of CCAM, and studied the capacities, roles and responsibilities of relevant organisational units in the local administration.

Automation-ready Forum in Helmond


Figure 22: Automation-ready Forum in Milton Keynes - Youth Parliament

Helmond

Intended that all local, internal stakeholders of the municipality of Helmond, from policymakers to implementers, see the possibilities or impossibilities of self-driving vehicles, so they can set the objectives and measures for the future. Due to its focus on Smart Mobility and status as a living lab, Helmond participates in several research projects related to CCAM, and thus aimed to create a common understanding and holistic coordination of its efforts in this field.

Milton Keynes

A series of workshop /fora were designed to target specific groups who would be critical to the development of future CCAM initiatives, especially for the transition phase. This meant working with: younger people – those approaching adulthood and to using independently, transport systems; and older and disabled group - with specific transport and mobility needs.

Main conclusions

- Without a comprehensive understanding of the needs and views of all local stakeholders, it will be more difficult for local and national decision makers to embrace new technology that is fundamentally disruptive to current transport system and may indeed have short term negative impact until the technology matures.
- That bespoke methods can be adopted to engage with key stakeholder groups, and by using effective communication techniques, meaningful outputs can be achieved.
- Resources must be provided proactively, such as specific experts in various administrative units.

Automation-ready planning framework

In order to provide guidance and empower local authorities to make critical and reasonable decisions about the introduction of CAVs into their road networks, CoEXist has developed an automation-ready planning framework. It includes elements of strategic urban mobility planning (SUMP) for CAVs and a guide for urban transport planners with concrete actions to be followed. Furthermore, it brings together methodologies and tools developed within the project, as well as lessons learned from their implementation.

The automation-ready framework is organised in three phases, which do not correspond to specific time period as different cities may be in a different phase depending on local circumstances. Also, phases can overlap, and actions might be taken in parallel and be closely interlinked.

For each phase, a set of measures are recommended to facilitate the reduction of uncertainties and to ensure a smooth transition into the sustainable deployment of CAVs in cities. The figure presents an overview of the proposed phases towards automation-readiness and some examples of the types of measures considered for each aspect of urban mobility.

Reduce uncertainties through:

- Guidance on technology, analysis methods, impacts and measures
- Clear-headed and informed decisions about automation
- Automation FAQ for cities

Mobility Aspect	Automation Awareness	Planning for Automation Readiness	Implementation of Automation Ready Measures
Policy	**Policy screening:** Liveability as top priority - how can CAVs contribute to it?	**Reassessment** of strategic mobility plans: incorporating new mobility forms	**Mobility pricing** for "SPAM" roaming cars
Infrastructure	Is there a conflict between **people friendly** vs. automation friendly?	Preparation of **physical and digital** infrastructure	**Modifications** to infrastructure and accompanying traffic code
Planning	**Engagement** with citizens & support testing **activities** and research	Update travel demand **models** and evaluate road **capacity needs**	Assessment of required land use changes based on integrated **land use** and transport modelling tools
Capacity Building	**Try out level** 1 & 2 functionalities	Identify **new skill requirements** - 'less concrete more bytes'	**Organisational restructuring** for traffic management and public transport operations
Traffic Management	Road **authorities** need to engage with OEMs	**Back office for data exchange** in traffic management	**Defining data management responsibility** with new management schemes

Figure 23: Overview of the phases towards automation-readiness (Rupprecht Consult)

Road Vehicle Automation in Sustainable Urban Mobility Planning (Practitioner Briefing):

As part of the SUMP EU Guidelines update process, CoEXist has lead the development of a Practitioner Briefing on planning for road vehicle automation, which provided an initial basis of support for authorities to undertake the challenge of addressing CCAM in SUMP processes.

The document provides guidance on key tasks and factors to be considered within the SUMP methodology, mapping for the main uncertainties and discussion guiding principles on how to mitigate them. Furthermore, it delivers recommendations on how the eight SUMP principles can be applied in the context of CCAM, and shares useful tools and good practice examples.

Lessons learnt and recommendations

CoEXist has delivered tools for a structured approach of assessing future scenarios and handling uncertainties, including automation-ready modelling tools for both microscopic traffic flow simulation and macroscopic travel demand modelling, in addition to a comprehensive modelling approach and impact assessment tools and methodologies, and an automation-ready planning framework.

The new features implemented in traffic modelling tool to allow simulation of automated vehicles, modellers should be aware of the assumptions and system parameters to be defined, such as how the vehicles should or will behave. To guide the definition of these behavioural parameters, CoEXist has developed a set of Driving Logics. Still much research is ongoing, and there are no fixed rules or standards and high uncertainties remain.

Although the tools developed enable the assessment of innovative infrastructure measures, use case implementation showed mobility improvements mainly for high automation and penetration levels, and open-questions remain on when and how urban road infrastructure and road design should change to facilitate the transition phase towards CCAM.

Inserting CAVs in traffic does not necessarily improve efficiency. Depends on penetration rate, driving logic and spatial conditions. Higher penetration rates, combined with more advanced CAVs, will start to generate some gains.

Yet, the potential deterioration of urban mobility at the initial stages of CAV deployment, encountered in some use case simulation results, accentuates the need for cities to actively plan for the transition phase, closely regulating where and how CCAM is deployed, the types of services and behaviour implemented.

To do so, it is important to define a clear vision for CCAM, materialised in realistic and measurable targets, that will enable effective expectation management, challenging the positive hype around CAVs- in particular for the transition phase.

Cities should also be aware of the various opportunities, and challenges that arise from CCAM deployment. For instance, considering its potential role in transforming travel behaviour, and facilitating modal shift towards integrated Public Transport with, for example, automated (shared) fleets. A structured & well-informed decision-making process, through holistic frameworks, is required to ensure sustainable and affordable services that align with local policy goals and respond to user needs.

How can local authorities shape CAV deployment in alignment with their policy goals?

- Authorities should look at planning for Cooperative Connected and Automated Mobility (CCAM) as an element of a more **fundamental change process: proactive action** to get ready for the challenges of conducting planning processes towards CAV deployment.
- Planning for CCAM should be **based on analyses of all modes** and supported by all **stakeholders** (and not on an SAE perspective).
- Transport and infrastructure planning through adequate tools: **automation-ready modelling functionalities** & **impact assessment** framework, with strategically defined **Key Performance Indicators** in relation to **local policy goals.**
- In addition to (old) risks, **new opportunities** for sustainable urban development arise, which can potentially spur **flexibility** and create **room for experiments.**

Figure 24: CoEXist Consortium Meeting in Helmond

Authorities should look at planning for CCAM as an element of a more fundamental change process

(…)use case simulation results, accentuate the need for cities to actively plan for the transition phase, closely regulating where and how CCAM is deployed.

Glossary

Automation-readiness:

capability of making structured and informed decisions about the deployment of Cooperative Connected and Automated Mobility.

CCAM:

Cooperative, Connected and Automated Driving

CAV:

Connected Automated Vehicle

AV:

Automated Vehicle

Levels of Automation:

Degree of automation of a driving system, in accordance to the scope of its functionalities.

SAE levels of driving automation:

Classification of driving automation levels, as defined by SAE International: https://saemobilus.sae.org/content/J3016_201806

Operational Design Domain:

specific set of conditions under which an automated driving system is designed to operate properly. It can include environmental conditions such as weather and visibility due to daytime/night time, geographical conditions, roadway types, traffic laws and regulations, and speed range, among others

SUMP:

Sustainable Urban Mobility Plan/Planning.

C-ITS:

Cooperative Intelligent Transport Systems

CoEXist Partners

Duration

May 2017 – April 2020

More Information

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