D1.5

Report on CoEXist's International Cooperation

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Table of contents

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1 Introduction

The key component of international cooperation within CoEXist has been initiated by the agreement of the European Commission (EC) and the U.S. Department of Transportation (USDOT) to sponsor a sponsor a twinning initiative to encourage collaboration between mobility-related projects in Europe and the United States.

In this frame, the CoEXist project has been selected as the EU project to establish a twinning relationship with relevant USDOT-funded projects on the analysis, modelling and simulation (AMS) of CAVs, aiming towards the coordination of activities and research collaboration, on the basis of mutual benefit.

1.1 Twinning Agreement

A Twinning Agreement was signed on 26th February 2018 between CoEXist and two FHWA funded research projects:

- (1) **Development of an AMS Framework for CAV systems**, which aims to determine the main knowledge, data and tool gaps associated with modelling CAV applications – and to create a conceptual AMS framework that addresses these gaps.
- (2) **Developing AMS Tools for CAV Applications**, with the goal of developing a uniform suite of AMS tools and implementation guidance – producing an accessible, promotable, ready-to-use toolbox for state DOTs and MPOs.

The two twinning groups agreed to actively cooperate and exchange on the following topics of their research projects:

- Development of an 'Analysis, Modelling and Simulation (AMS) Framework' for connected and automated vehicles;
- Exchange of information about use cases and case studies that will apply the AMS Framework; and
- Cooperation on AMS tool development for connected and automated vehicles.

1.2 Working together: joint activities and events

The twinning activities encompass conference calls and workshops at conferences with the goal of exchanging project results and deliverables, sharing insights gained from case studies or conducted research, and discussing the development of conceptual as well as methodological approaches to developing automation-ready AMS tools and frameworks. Said cooperation has previously taken place during face-to-face workshops in the context of the 2018, 2019 and 2020 TRB Annual Meetings, at CoEXist's Consortium Meeting in Helmond, and at the CoEXist Final Conference, which was held as a virtual conference on March 25 and 26, 2020.

During these workshops, EU and US researches presented updates of the work and progress made in their respective projects, spurring interesting discussions around the different conceptual and methodological approaches, and providing valuable feedback for its improvement.

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1.2.1 TRB Annual Meeting 2018

After several preparatory conference calls, the first face-to-face twinning meeting between the EU and US delegations took place as part of the TRB annual meeting on 11th January 2018 in Washington D.C., USA:

- At this workshop, the EU delegation was represented by: Rupprecht Consult (Siegfried Rupprecht & Bernard Gyergyay) as the Project Coordinator and WP leader; University of Stuttgart (Markus Friedrich) & PTV Group (Jochen Lohmiller), who contributed their very relevant expertise on transport modelling, analysis and simulation; and FEHRL (Thierry Goger), providing a key perspective on road infrastructure and facilitating the liaison between the delegations through the membership of FHWA to FEHRL.
- The US delegation was represented by US DOT (Joe Bared, James Sturrock, Gene McHale, Jeremy Raw, Scott Smith & Brian Cronin), University of Berkley (Steven Shladover, Alexander Skabardonis & Xiao-Yun Lu), Leidos (Zhitong Huang & David Hale), Northwestern University (Hani Mahmassani) and Texas A&M University (Alireza Talebpour).

This meeting allowed to contextualise both teams on each projects activities, calendar and approaches, including topics as CoEXist's automation-ready framework, US' AMS framework, driving logics considered, and FAQ on automation, among others. It also focused on finalising the Twinning Agreement and defining the cooperation agenda (conference calls, face-to-face workshops, etc.)

Figure 1: EU-US Twinning Meeting during TRB 2018 (CoEXist, 2018)

1.2.2 TRB Annual Meeting 2019

A second face-to-face workshops took place in the frame of TRB 2019, in Washington D.C.

- US projects where represented by Rachel James (FHWA), James Sturrock (FHWA), Steve Shladover (PATH), Alex Skabardonis (PATH), Xiaoyun Lu (PATH), Hani Mahmassani (Northwestern University), Xiaopeng Li (xiaopengli@usf.edu), Zhitong Huang (Leidos), David Hale (Leidos), Jeremy Raw (FHWA), Brian Cronin (FHWA) and Scott Smith (Volpe).
- CoEXist was represented by Siegfried Rupprecht (Rupprecht Consult), Johan Olstam (VTI), Jochen Lohmiller (PTV Group), Markus Friedrich (University of Stuttgart), Thierry Goger (FEHRL).

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The discussion included more technical details on the CAV modelling approaches, assumptions and calibration, and differences in terminology and the understanding of driving logics (such as the 'All-knowing' behaviour and its implications).

Figure 2: EU-US Twinning Meeting during TRB 2019 (CoEXist, 2019)

1.2.3 5th CoEXist Consortium Meeting, Helmond (NL)

US twinning partners were invited to attend CoEXist's Consortium Meeting in Helmond, which included a twinning workshop on Friday 7 June 2019.

Rachel James (FHWA), Zhitong Huang (Leidos) and Steven Shladover (PATH / UC Berkley), attended presentations on CoEXist's activities and actively participated in the discussions, providing their feedback and perspectives. Given the stage of development in the project, much of the discussion focused on the use case implementation in CoEXist cities and the impact assessment tool under development for their evaluation.

After the consortium meeting, an EU-US Twinning Workshop was held, focusing on receiving updates from the US projects and their progress, and coordinating further collaborative activities, mainly a Special Session to be proposed for TRB Annual Meeting 2020.

Given the importance of such opportunity, the twinning partners have focused their efforts in the second half of 2019, in coordinating and preparing for the special session at TRB 2020. The concept developed during the meeting at Helmond, was based on drawing a parallel narrative of approaches in each party (US and EU), from the modelling framework and operational models, to the scope and parameters of the use cases studied in the projects. Please see the session's description and agenda in the next section for more information.

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Figure 3: 5th CoEXist Consortium Meeting & EU-US Twinning Meeting, Helmond (NL)

1.2.4 TRB Annual Meeting 2020

During the 2020 TRB Annual Meeting, there were several occasions within and outside of the official TRB agenda for US-EU twinning activities to be presented and discussed:

The first and principal of these, was the Lectern Session titled “Preparing for Connected & Automated Vehicles: Results from EU-US Research Collaboration. This session was the result of the successful cooperation between the twinning partners, who took advantage of this privileged occasion to share the their project findings and emphasize the comparison between the FHWA-projects and CoEXist approaches to simulate and analyse the impacts of CAVs on road infrastructure and mobility, with the goal of reaching common understanding of current challenges and research needs. The session was well-received by the large number of attendees and therefore successfully disseminated the findings of the participating projects and established the plea for further EU-US cooperation on this matter.

Lectern Session 1386 Tuesday, 14 January 2020, 8:00 AM – 9:45 AM

Preparing for Connected and Automated Vehicles: Results from EU - U.S. Research Collaboration

Rachel James, Federal Highway Administration (FHWA), presiding

Wolfgang Backhaus, Rupprecht Consult, presiding

Lectern

Operations and Traffic Management

Description: In early 2018, an agreement was signed between research contractors for the USDOT and the European Commission to “twin” three projects on the topic of developing connected and automated vehicle (CAV) driving behavior models and assessing their impact on the traffic stream. This special session will detail the twinning agreement, the developed CAV driving behavior logic and applications, the EU and US case studies, and a planning framework towards automation-readiness.

Moderation: Rachel James (FHWA) & Wolfgang Backhaus (Rupprecht Consult)

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Agenda:

Time	Presentation	Speaker(s)
5'	**US-EU Twinning Process**	Brian Cronin (Director of Office of Operations Research and Development, FHWA)
15'	**Twinned Project Structures and Objectives: Similarities and Differences** • Preparing public agencies for automation • Developing tools for modelling automation impacts	Rachel James (FHWA) & Wolfgang Backhaus (Rupprecht)
25'	**Modelling Automation: Framework and Specific Operational Models**	
5'	CAV Model Framework to Incorporate Transportation Supply and Demand Effects	Hani Mahmassani, (Northwestern)
10'	US: Stakeholder-Driven Selection of Freeway Connected Automation Concepts to Model	Steven Shladover (PATH)
10'	EU: Defining representative driving logics and urban operational scenarios to model	Johan Olstam (VTI)
35'	**Results: Impacts of Automation on Traffic Flow**	
15'	EU: Automation-ready traffic flow modelling and impact assessment in European cities	Jochen Lohmiller (PTV)
10'	US: I–66 Virginia Case Study of Connected Automation Impacts	Jiaqi Ma (University of Cincinnati)
10'	US: SR–99 California Case Study of Cooperative Adaptive Cruise Control Impacts	Hao Liu (PATH)
10'	**Modelling Impact of Automation on Travel Demand**	Markus Friedrich (University of Stuttgart)
5'	**Automation-Ready Framework**	Wolfgang Backhaus (Rupprecht)
5'	**Q&A**	All

To effectively present the results of the twinning cooperation, partners agreed to employ the AMS Framework (developed by US-partners) as common basis. This framework was applied to CoEXist,

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categorising the project's efforts and results to enable easy comparison with FHWA-projects.

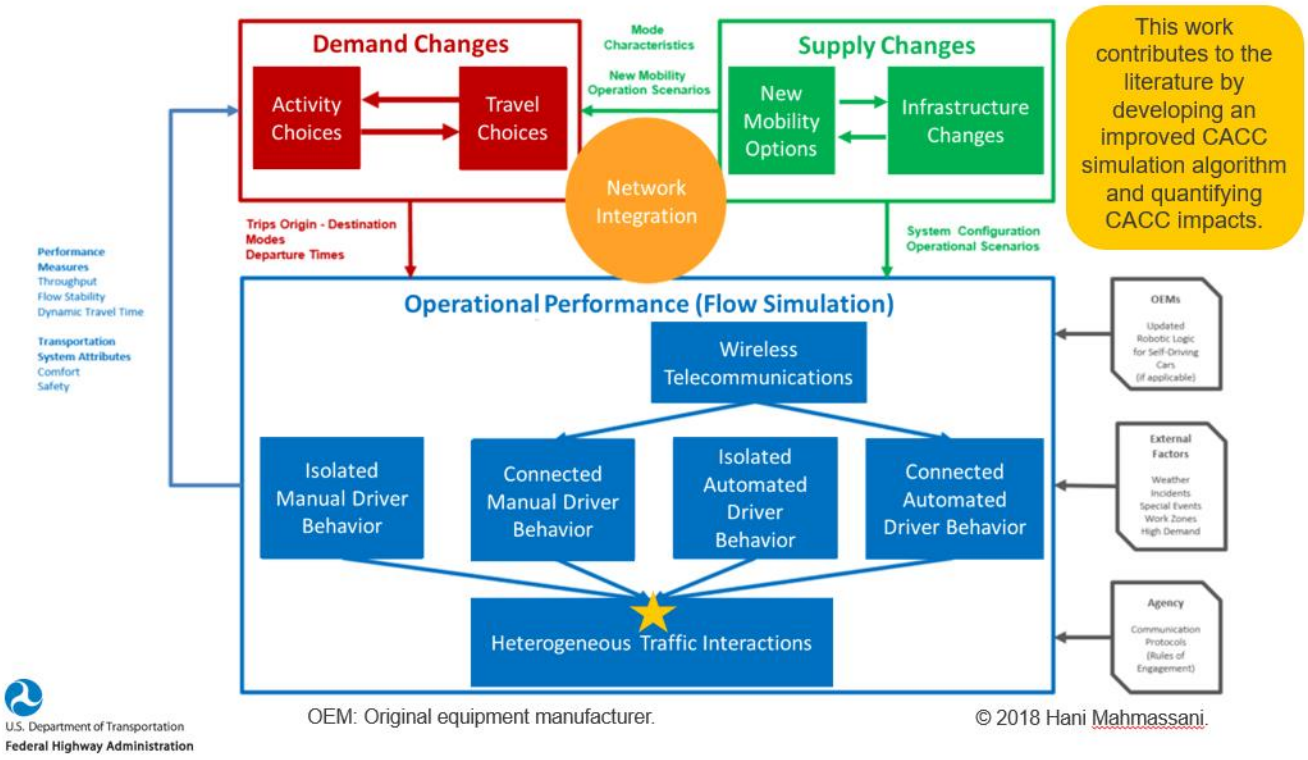

Figure 4: AMS Framework (Hani Mahmassani, FHWA, 2018)

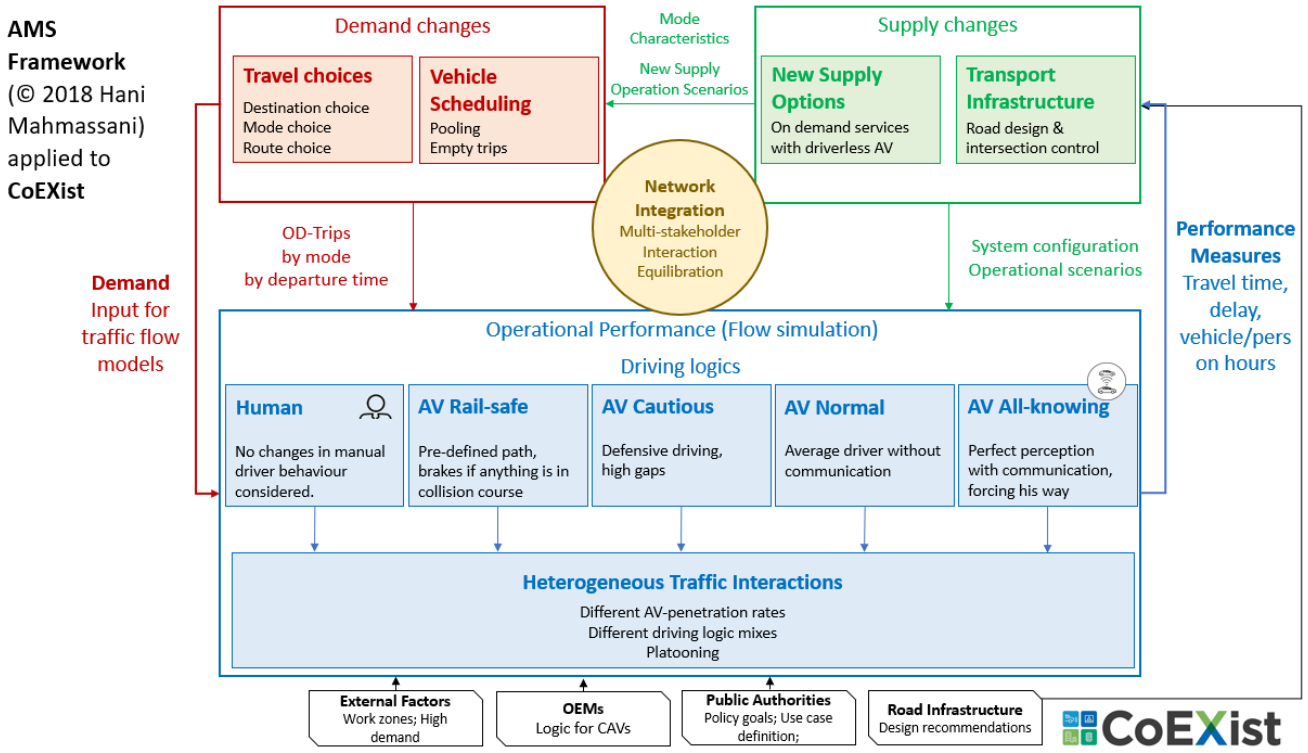

Figure 5: Application of AMS Framework to CoEXist

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CoEXist was also presented at the **FEHRL-FHWA Meeting**. In this session, Siegfried Rupprecht shared the results from CoEXist and the US-EU twinning cooperation - as a best practice example whose lessons-learnt can be practical for other cooperative initiatives. Additionally, as it had occurred in 2018 and 2019, partners participated in an **EU-US Twinning Workshop** on 16 January 2020, which served as platform for analysis and reflection on the obtained results of the modelling exercises of CAV impacts and empirical assessments of pilot projects, specifically pinpointing limitations and developing joint conclusions. Furthermore, the workshop was used to speak about upcoming activities and cooperation (also beyond) the project's finalisation, such as a joint session at AVS2020 (see section 1.2.6).

Figure 6: Speakers from the EU-US Research Collaboration session at TRB 2020

Figure 7: TRB 2020 Session on US-EU Twinning Research Collaboration

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1.2.5 CoEXist Final Conference

In the context of the CoEXist project, its final conference, hosted as a virtual event on 25 and 26 March 2020, was the last formal occasion for twinning activities between CoEXist and the FHWA-funded research projects 'Development of an AMS Framework for CAV systems' and 'Developing AMS Tools for CAV Applications'. Alongside presentations by speakers from VTI, PTV Group, the University of Stuttgart, the City of Helmond, the University of Cambridge, Milton Keynes City Council, the City of Stuttgart, the City of Gothenburg and Polis, Rachel James from the USDOT Federal Highway Administration spoke specifically about results of the second of the two FHWA-funded research projects.

Agenda:

Wednesday 25 March 2020

CET (UTC+01:00) — ***Moderator**: Siegfried Rupprecht, Rupprecht Consult*

13:45 Registration and technical support

14:00 **Welcome**, Siegfried Rupprecht, *Rupprecht Consult* & INEA (tbc)

Introduction to CoEXist, *Daniel Franco, Rupprecht Consult*

CoEXist tools

Automation-ready transport modelling and infrastructure assessment

14:10 **Overview of the CoEXist impact assessment approach and automation-ready transport (infrastructure) assessment tool**, *Johan Olstam, VTI*

14:25 Polls - Q&A

14:30 **Automation-ready modelling tools: microscopic traffic flow simulation,** *Charlotte Fléchon, PTV Group*

14:45 Polls - Q&A

14:50 **Automation-ready modelling tools: macroscopic travel demand simulation,** *Markus Friedrich, University of Stuttgart*

15:05 Polls - Q&A

15.10 **Toward the Development of Analysis, Modelling, and Simulation (AMS) Tools for Connected and Automated Vehicles (CAVs),** Rachel James, USDOT Federal Highway Administration (FHWA)

15:25 Polls - Q&A

15:30 *Break*

CoEXist impact assessment findings

Potential impact of vehicle automation in four cities, across eight scenarios:

15:45 **Helmond (NL): (i) multimodal signalised intersection and (ii) highway-urban road transition**, *Frank van den Bosch, city of Helmond*

16:00 Polls - Q&A

16:05 **Gothenburg (SE): (i) shared space; (ii) accessibility during long-term roadworks,** *Iman Pereira & Chengxi Liu, VTI*

16:20 Polls - Q&A

16:25 **Milton Keynes (UK): (i) drop off and waiting for passengers; (ii) priority at roundabouts,** *John Miles, University of Cambridge*

16:40 Polls - Q&A

16:45 **Stuttgart (DE): (i) network level travel time & mode choice; (ii) ridesharing,** *Jörg Sonnleitner, University of Stuttgart*

17:00 Polls – Q&A

17:05 **Lessons learnt & conclusions**, *Wolfgang Backhaus, Rupprecht Consult*

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17:15 End of the session

Thursday 26 March 2020

CoEXist training session	Polis Working Group Meeting
10:00 – 12:00 **Training: Modelling tools** Introduction to automation-ready modelling tools, PTV Vissim Demonstration Practical examples and exercises Limited availability:	*Meeting of the Polis Working Group on Traffic Efficiency* POLIS CITIES AND REGIONS FOR TRANSPORT INNOVATION *For Polis members only*

Workshop: What next for cities and CAVs?

moderated by Siegfried Rupprecht, Rupprecht Consult

14:00 ***Welcome,*** *Siegfried Rupprecht*

14:05 **Automation-ready framework for city authorities,**
Wolfgang Backhaus, Rupprecht Consult

14:20 **CoEXist – Roadmap towards automation-ready cities**
Brian Matthews, Milton Keynes city council
Susanne Scherz, city of Stuttgart
Mikael Ivari, city of Gothenburg
Frank van den Bosch, city of Helmond
10 min per speaker (including 3min Q&A)

15:00 *Poll & self-assessment of automation-readiness*

15:15 **Towards automation readiness - challenges for infrastructure,**
Suzanne Hoadley, Polis

15:30 **Interactive group discussion**
Key issues for cities, including change and expectations management, future proofing sustainable mobility policy, future proofing infrastructure investment and citizens engagement citizens.

15:50 **Lessons learnt and conclusions,** *Wolfgang Backhaus, Rupprecht Consult*

16:00 End of the session

Highlight input from the USDOT side, Rachel James (FHWA) described the research and results from FHWA-funded project in her presentation, named 'Towards the Development of Analysis, Modelling, and Simulation (AMS) Tools for Connected and Automated Vehicles (CAVs)'. This presentations explained the objectives of the AMS Framework for CAV systems, namely measuring demand effects, supply changes, operational performance, network integration. Also, two case studies on first applications of an AMS tool for CAV were discussed and provided conclusions about short-term impacts from lower automation levels with advanced driver assistance systems (ADAS). As a main area for improvement, the need for further data availability was highlighted.

There were discussions and Q&A sessions after every presentation that at times voiced valuable feedback for speakers and the entire CoEXist project consortium. It was also shown that the EU-US Twinning

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Agreement has helped both sides and all three projects advance through the exchange of expertise and provided the opportunity for “sanity checks” on both ends.

1.2.6 Automated Vehicles Symposium 2020

This international cooperation continued beyond the project finalisation, with further activities for knowledge exchange and the broad dissemination of the projects results.

Building upon the continuous US-EU research collaboration, twinning partners presented a breakout session proposal for AVS 2020. This session was first discussed during the US-EU Twinning Workshop in Washington D.C on January 2020, and was further prepared, under the leadership of Rupprecht Consult, during the next months.

In addition to Rupprecht and Polis (CoEXist), twinning partner representatives such as Rachel James & Sarah Sun (FHWA), Hannah Rakoff & Scott Smith (Volpe) and Jiaqi Ma (University of Cincinnati), other session organisers and speakers included Claire Depre (European Commission), Martin Russ (AustriaTech, INFRAMIX project), Nikolas Thomopoulos (WISE-ACT), Maaike Snelder & Bart van Arem (TU Delft, STAD project), Robert Dingess, (Mercer Strategy) and Samuel Labi (Purdue).

The session called ‘No-Regret Options for Policy Making and Infrastructure Development’, took place on July 28, 2020 online, as the AVS2020 had to be fully adapted to a virtual format, due to the COVID-19 pandemic.

The session focused on the (preliminary) certainties derived from modelling and empirical assessments of CAV impacts, to facilitate decision-making and identify no-regret options for policy and infrastructure for CAVs. In this context, no-regret options were understood as preparatory measures and policies required for (almost) any automation scenario, that facilitate CCAM implementation during the transition phase and create quick co-benefits elsewhere (e.g. well-maintained road markings, C-ITS implementation). It aimed to support policy makers to take active role in shaping CAV deployment in pursuit of public policy goals.

In this way, this AVS 2020 session presented the main results from the involved projects and a joint analysis of their impact to define key recommendations for action planning in cities and regions, as well as funding and research priorities.

Key Findings and Lessons Learned

The main no-regret options derived were:

- Transform planning practices from the ‘predict then act’ paradigm, towards agile and adaptive decision-making, aided by capacity development for local authorities, robust scenario simulations, and cross-sectoral cooperation.
- Take incremental steps towards the deployment of CCAM-services,
    - upgrading motorways and regional roads to AV-readiness – support mixed traffic with enhanced infrastructure,
    - further developing C-ITS capabilities (e.g. I2V) in these types of roads, enabling support to AVs and conventional vehicles and optimising traffic management,
    - regulating where CAVs are allowed to operate (e.g., motorways/regional roads, based on further research/consultation, and assessment of implementation scenarios),

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    - gradually adding dedicated lanes, for regulated CCAM-services (on interurban roads).
- Enhance public-private cooperation to develop business models that prioritise CCAM based on collective, car and ride sharing services, responding to real societal needs and contributing to sustainability goals.
- Develop integrated legal and policy framework to regulate CAV deployment and service provision.

Outcomes & Research Needs Statements

- Formulate strategic R&D agenda to guide cooperation of all actors along the entire value chain, towards a common vision for CCAM deployment (in pursuit of public policy goals)
- Develop data sharing strategies for cross-sectoral and public-private cooperation, and enable informed decision-making based on existing empirical basis
- Further advance the development of standardized and interoperable C-ITS capabilities
- Investment into mobility services from a business model perspective while steering innovation to solve current problems (e.g. carbon-neutrality, covid-19 crisis)
- Comprehensive capacity building program for authorities to support planning and deployment of CCAM

1.3 Lessons learnt and conclusions from the research collaboration

Through the knowledge exchange efforts and joint discussions twinning partners were able to understand the modelling and analysis approaches followed by each project, and reflect on their results and key findings. This served to enrich the knowledge base that CoEXist worked upon, enabling partners to validate modelling approaches and encountered results.

In addition, during the twinning workshops, discussions advanced around each project's activities and findings, twinning partners to serve as external experts, critically assessing the work done and providing valuable feedback for its improvement. Some of the topics that guided the discussions were: the development of a framework and effective tools to enable CAV transport planning; the definition of CAV control logics and driving behavioural parameters; the safe integration of CAVs in mixed road environments; the interaction and communication of CAVs with other road users such as pedestrians, bicycle drivers and conventional vehicles; the challenges and opportunities of V2I (Vehicle-to-Infrastructure) communication; the design and adaptation requirements of road infrastructure; and the assessment of CAV's impacts on road infrastructure, among others.

Through this critical feedback, twinning partners could perform a sense check and review of some CoEXist's developments, such as: the defined driving logics, with, for instance, a useful discussion around the specification of the *All-knowing* case; or CoEXist's general conclusions and design recommendations.

Moreover, through EU-US twinning activities, CoEXist had direct access to the results of completed research within the US projects, which address very similar research questions, and in this way learn from different approaches. For instance, University of Berkley (Steven Shladover), provided PTV with useful results of their work on AV-modelling and the differences from human driving modelling, such as car-following and lane-changing characteristics. Later on, results and key conclusions from the modelling and impact assessment exercises within FHWA projects, were presented at CoEXist's final conference and TRB2020 joint lectern session, leading to a common understanding of the impacts of CAVs in mobility and common recommendations derived, the some of which are presented below:

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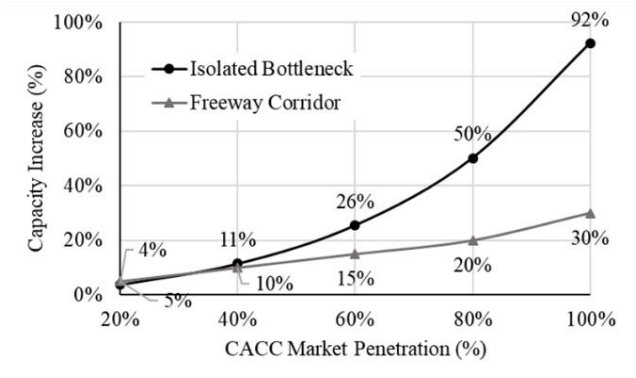
Common understanding of CCAM's impacts:

- Traffic performance improvements as market penetration rates increase, for higher automation levels
- Importance of infrastructure-to-vehicle (I2V) applications to maximize the freeway corridor performance (e.g., benefits of speed harmonization and cooperative merge, even at lower penetration rates).
- Traffic flow benefits of platooning implementation



Source: FHWA.

The cooperation led to a joint understanding of the CCAM modelling, analysis and planning frameworks developed by each project. The table below presents a comparison of the followed approaches, its similarities and differences.

FHWA Projects	CoEXist (EC)
Modelled CAV applications were selected based on potential national impact.	Prioritises specific local needs: bottom-up approach
Emphasis placed on freeway applications	Focus on urban infrastructure and network
Both based on interests of stakeholders and the desire to support decision-making.	
Models designed to be platform agnostic so they can be implemented in multiple simulation platforms.	CoEXist developed generic scripts and modelling parameters and worked on the basis of commercial software.
Research focused in advancing the traffic flow modelling capabilities (operational performance).	Developed traffic flow and travel demand modelling functionalities, and a urban mobility planning framework, to guide its implementation.
Emphasis on lower levels of automation and effects of connectivity/cooperation.	Focus on higher levels of automation: driving behaviour when an automated driving system is responsible for the vehicle operation
Both teams aim to evaluate the impacts of CAV technology on mobility and road infrastructure, and to enable informed decision-making through the provision of adequate tools, methodological guidance, useful recommendations and lessons learned.	

As noted, the EU and US approaches for the development of automation-ready modelling tools are similar. However, the implementation of such simulation tools does show some differences, such as developing scripts that work with existent commercial products or focusing on simulations logics and algorithms

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developed by universities. Also, the use cases that focus on specific infrastructure sections or road network impacts.

The twinning partners on both sides have agreed on the current scope and limitations of such models. It is clear that CAVs will have many complex and interdependent impacts on traffic network supply and demand. And that they will also affect trip generation, trip distribution, mode split, route choice, occupancy, speed, headway, fundamental diagrams, and so on. Even likely including circular dependencies between many of these effects. Thus, this initial generation of analysis, modelling, and simulation tools will not be able to fully capture all of these elements. Instead, they will serve as a starting point for CAV AMS tools that will become more robust over time. It was also recognised that there is a need for sufficient CAV field data to calibrate the developed models and diagrams (e.g., volume to density fundamental diagram). This limits the capacity to handle uncertainties in the field.

Given the initial stages of development, high levels of uncertainty and modelling limitations, the teams have underscored the key importance of continuous knowledge exchange and cooperation, and developing a standardized language/terminology to allow for transferability and facilitate communication.

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2 Partners

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