



Strengthening capacities of road authorities to plan for the transition phase of co-existence of conventional and connected and automated vehicles

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#H2020CoEXist

@H2020_CoEXist



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What is CoEXist?

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

To bridge 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

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

CoEXist approach



**Automation-Ready
Transport Modelling**

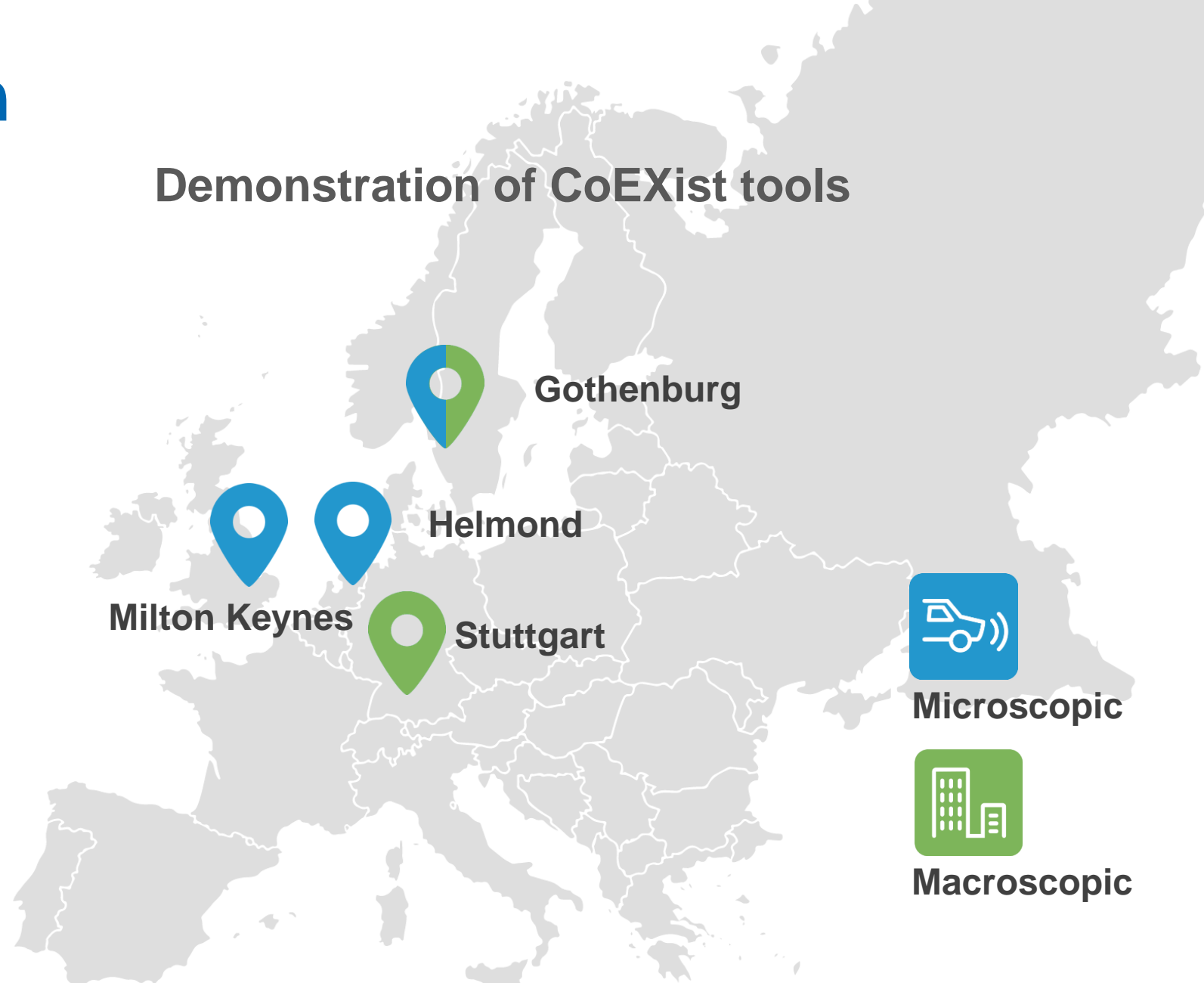


**Automation-Ready
Road Infrastructure**



**Automation-Ready
Road Authorities**

Demonstration of CoEXist tools



Microscopic



Macroscopic



Automation-ready transport modelling tools



RENAULT

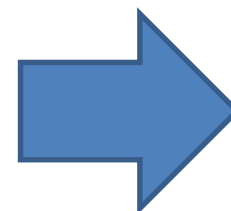
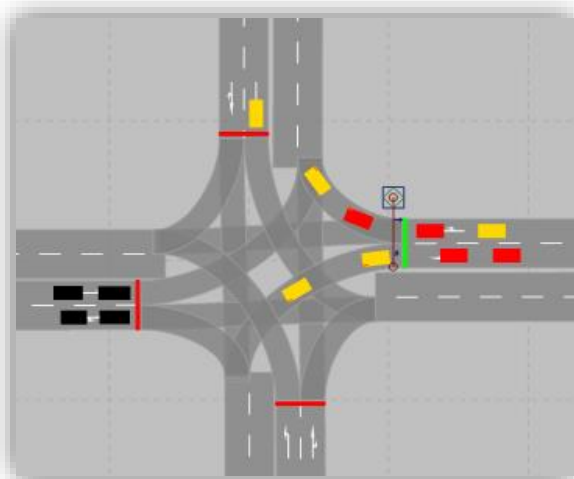
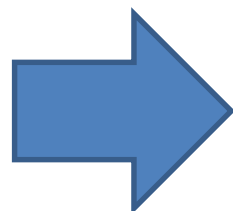
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Micro

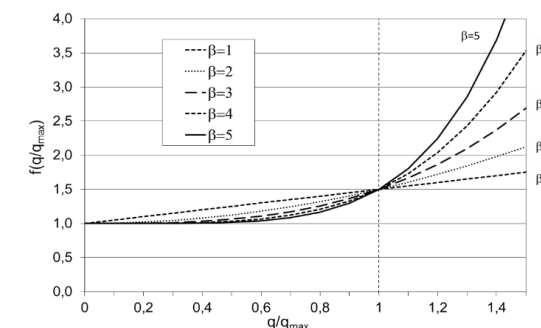
PTV VISSIM



Macro

PTV VISUM

- Capacity
- Volume – Delay Function



CoEXist's Modelling approach

- SAE levels focus on
 - To what extent the vehicle drive itself,
 - Where it can drive itself
 - Who is responsible for the driving
- but do not specify how driving behavior vary between or within the levels
- **CoEXist focus:** driving behavior when an **automated driving system (ADS)** is **responsible** for the vehicle operation:
 - CAV-behaviours specified by functionally defined **driving logics**: i.e., in terms of **how and where they can operate safely** (disregarding which technologies make this possible).
 - AVs comply with the road regulation and the code of the road, e.g. comply with speed limit

SAE level	Short description
0 – No automation	Full-time performance by a human
1 – Driver Assistance	Assistance system of either steering or acceleration/deceleration
2 – Partial Automation	Automation of some parts of the driving task
3 – Conditional Automation	Self driving but driver responsible and required to intervene if necessary
4 – High Automation	Self driving in some environment – driver not responsible
5 – Full Automation	Self driving everywhere



Driving logics

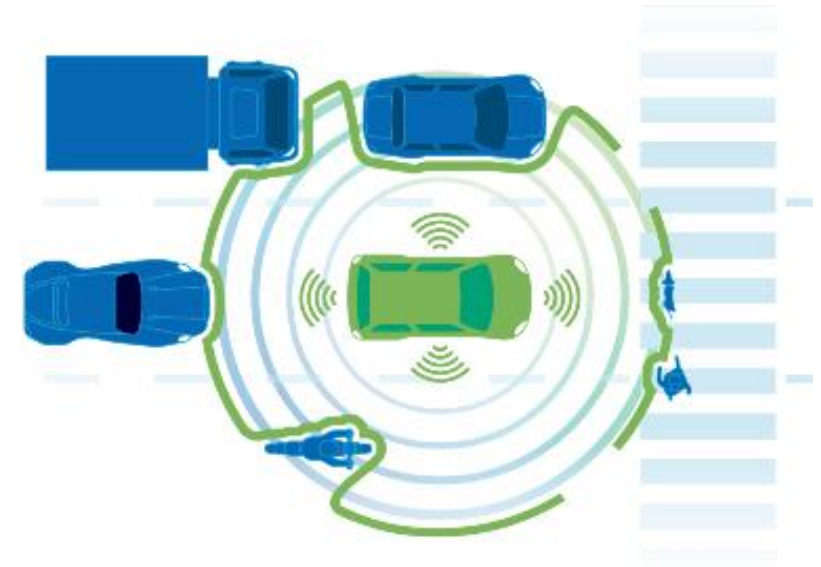
- Rail safe
 - Follows pre-defined path
 - Brick-Wall-Stop distance
 - Switch principle
- Cautious
 - Brick-Wall-Stop distance; requirement for manoeuvres
 - Require large gaps; slows down every time its sensors can have blind angles
- Normal
 - Similar to a human driver but with the augmented (and/or diminished) perception due to sensors.
- All-knowing
 - Perfect perception and prediction of the behaviour of other road users. Capable of offensive driving whenever needed, without causing accidents.



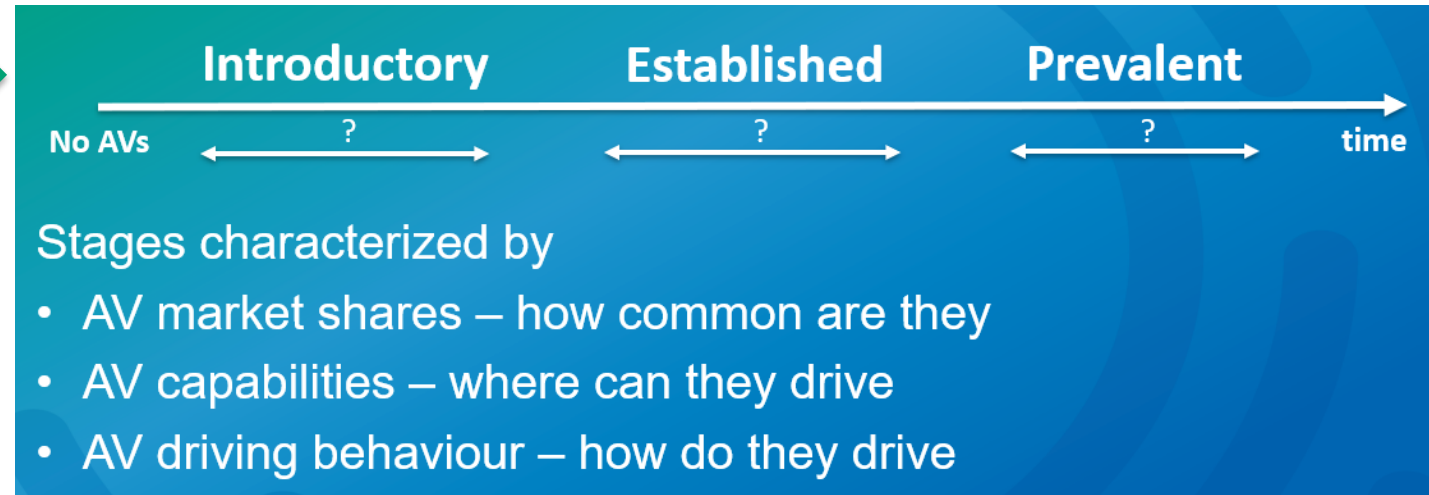
Modelling approach

Variables (selected uncertainty factors)

- Level of automation
 - AV-class (basic, intermediate, advanced)
 - Driving logic
- Travel demand
- Traveller behaviour adaptation (e.g., travel time perception)



Stages of coexistence (introductory, established or prevalent use of CAVs) →



Road environments

(motorway, arterial, urban street or shared space)

Types of vehicles

(cars, trucks, buses and minibuses)

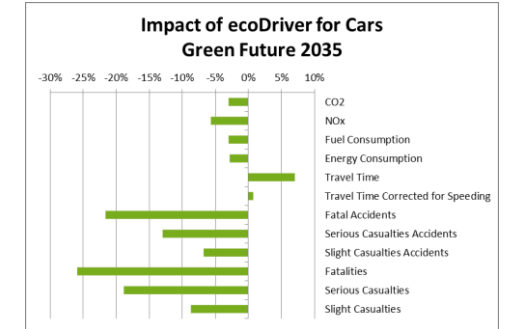
Example relation between AV-class, driving logics and operational design domain (ODD)

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



Automation-ready Road Infrastructure

- How to deduce automation-readiness from traffic models outputs?
 - Traffic models delivers raw data and traditional metrics
 - Define combined metrics and compare to “baseline”
- Developed performance metrics for assessment of CAV-readiness with respect to
 - Safety
 - Traffic performance
 - Infrastructure space efficiency
- AV-ready hybrid infrastructure assessment tool.
- **Discuss CAV-readiness in the infrastructure/road design perspective**



Automation-ready Road Authorities: CoEXist Use Cases

Gothenburg, Sweden

- Shared space
- 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 3: Helmond, NL

Signalized intersection including pedestrians and cyclists



Microscopic



Imagery ©2017 Google, Map data ©2017 Google 20 m



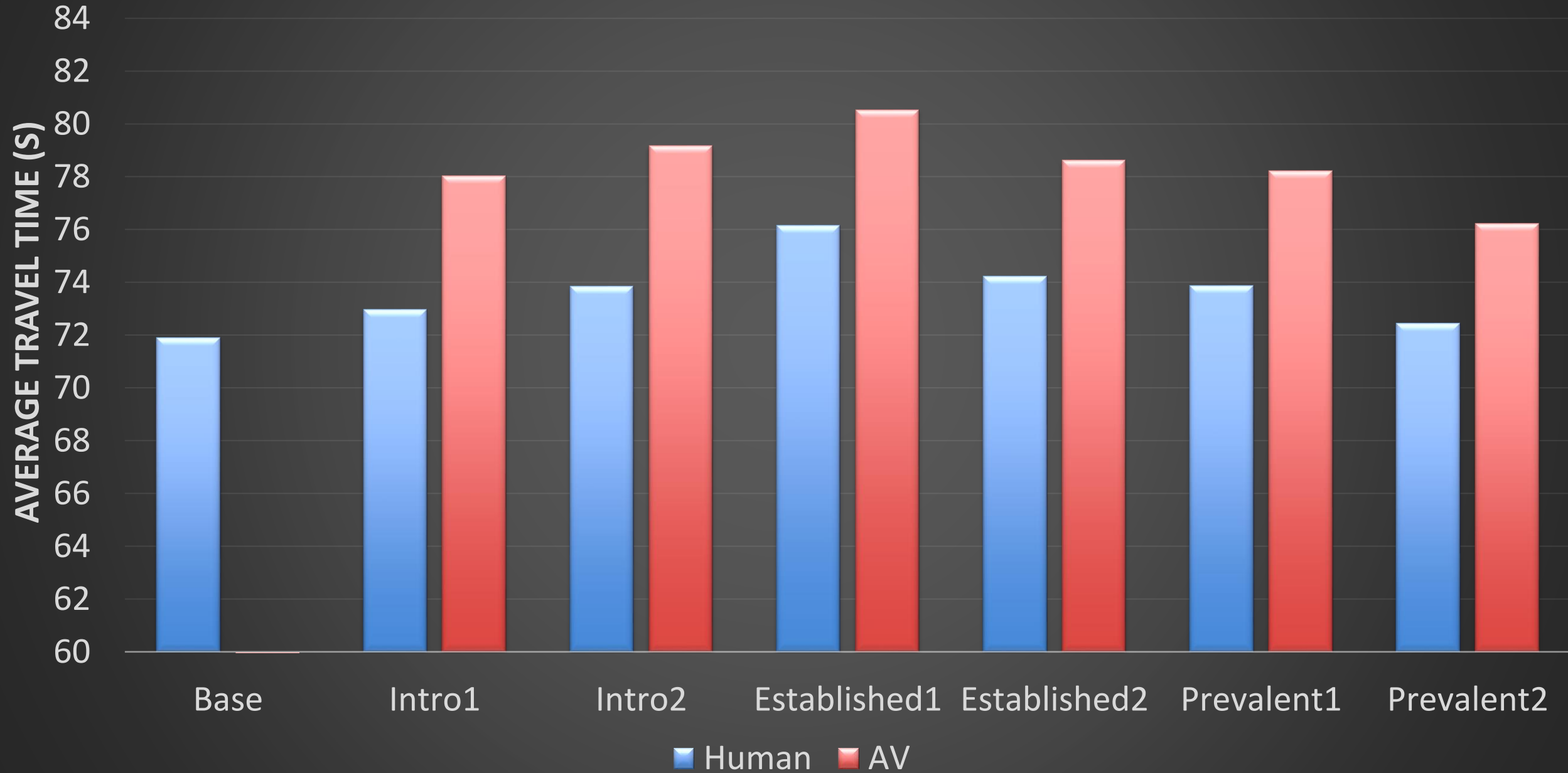
Experimental design - Urban

Road type	Driving logic: Manual (M), Cautious (C), Normal (N), All-Knowing (AK)		
	Basic AV	Intermediate AV	Advanced AV
Motorway	Cautious	Normal	All-knowing
Arterial	Cautious	Normal	All-knowing
Urban street	Manual	Cautious	Normal
Shared space	Manual	Manual	Cautious

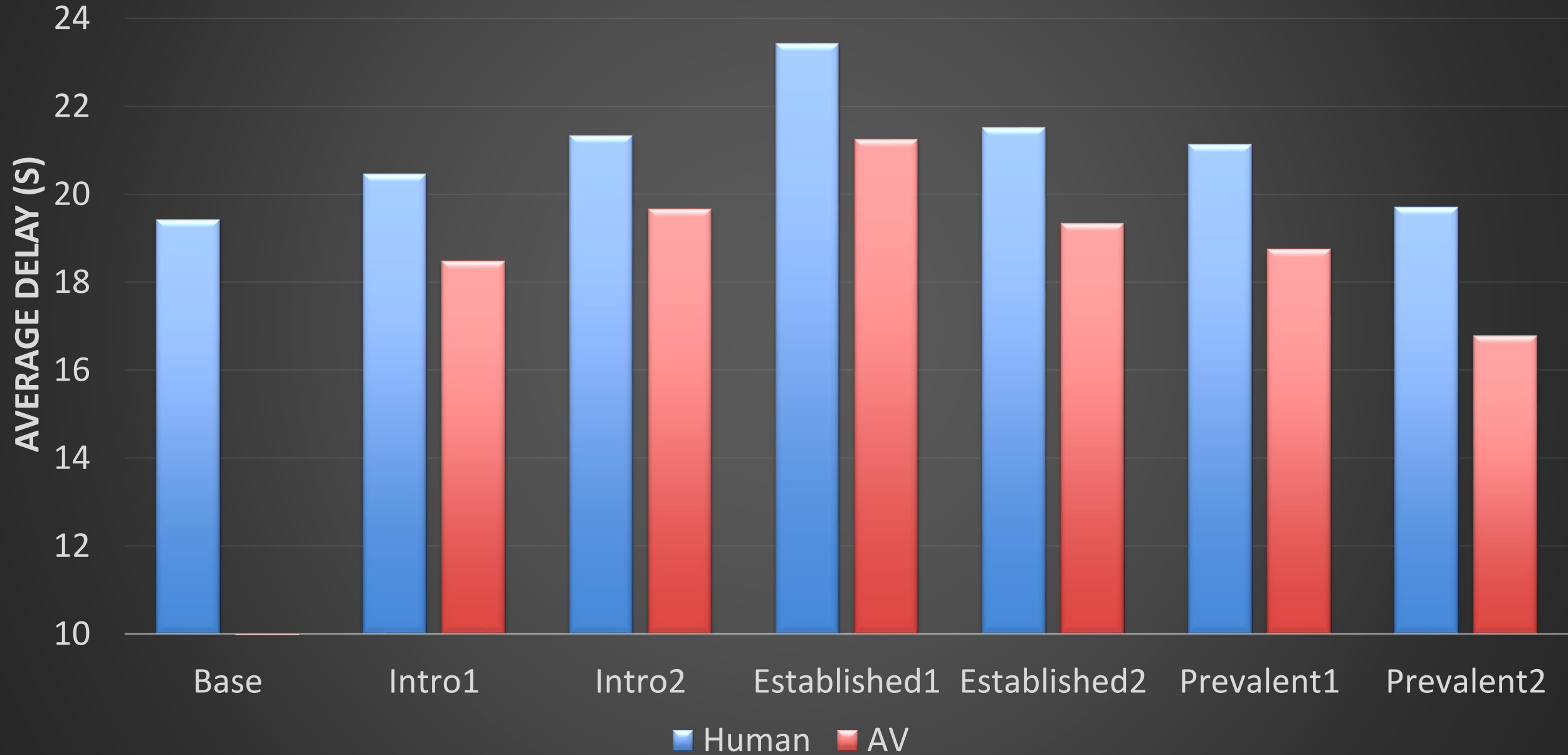
Stage	AV penetration	Ratios of AV class		
		Basic AV	Intermediate AV	Advanced AV
Today (No AV)	0	0	0	0
Introductory 1	25%	80% Manual	20% Cautious	0
Introductory 2	25%	20% Manual	80% Cautious	0
Established 1	50%	20% Manual	80% Cautious	0
Established 2	50%	0	50% Cautious	50% Normal
Prevalent 1	75%	0	50% Cautious	50% Normal
Prevalent 2	75%	0	0	100% Normal



Average travel time (s) - Urban



Average delay (s) - Urban



Use case 3: Helmond, NL

Signalized intersection including pedestrians and cyclists



Microscopic

Conclusions:

- **Travel-time/delays increase** for AVs, in comparison with CV.
 - Probably due to full speed compliance of AVs
 - Decreased saturation flow due to cautious behaviour
 - 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 AV-class (advanced), results are comparable to baseline situation (no AVs)



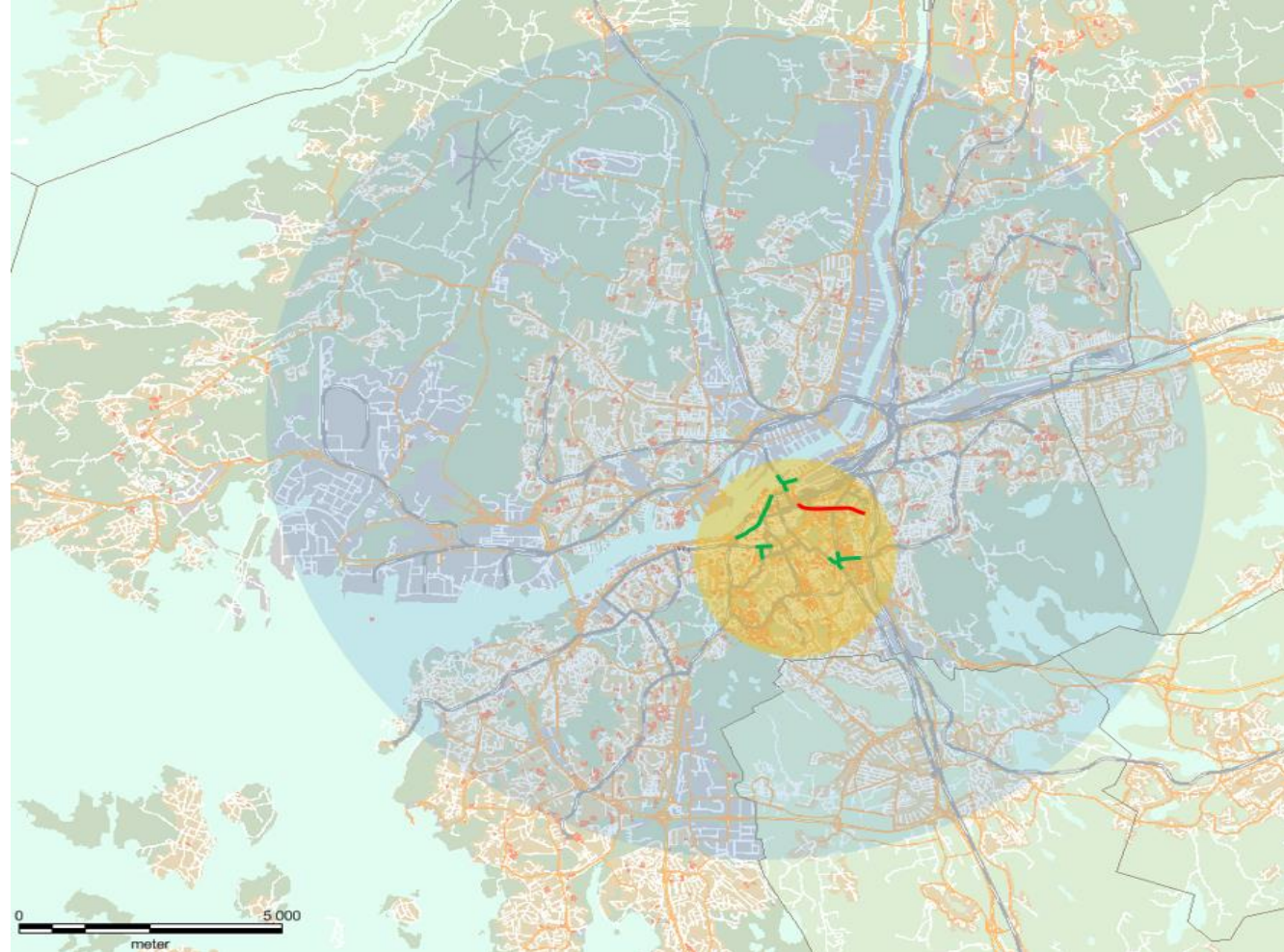
Use case 2: Gothenburg, SE

Accessibility during long-term construction works



Macroscopic

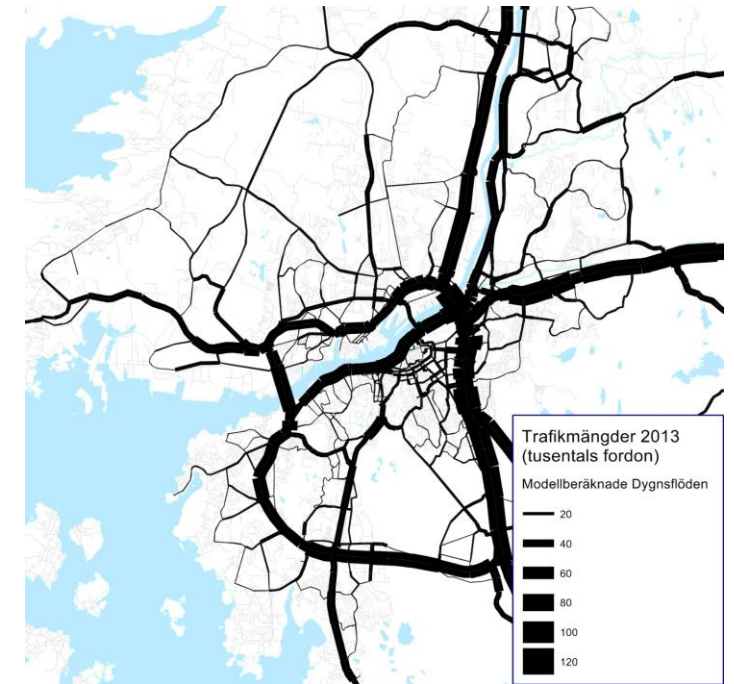
- Long term construction period for Gothenburg
- Evaluating AV introduction to traffic performance.
- AV introduction might enable new types of measures.



Use case 2: Gothenburg, SE

Accessibility during long-term construction works

- Aim and questions investigated
 - How does the introduction of AVs (at different penetration rates) affect route choice and total travel time/delay?
 - Evaluate the effectiveness of the **proposed measures** to relieve congestions under the intensive construction period.
 - Adding special dedicated AV lanes at Göta Tunnel.
 - Combined “Bus+AV” lanes.
- Study area characteristics
 - Includes both urban core and rural area.
- Brief description of the traffic situation
 - Severe congestions during peak hours.
 - E6 motorway in the north-south direction.
 - E20 motorway from the east.



Use case 2: Gothenburg, SE

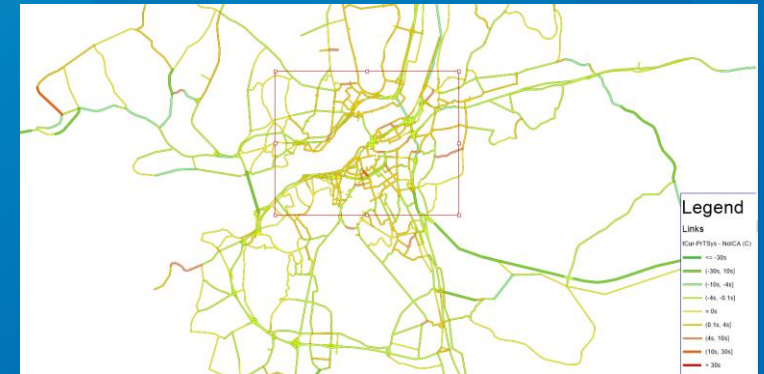
Accessibility during long-term construction works



Macroscopic

Conclusions: current infrastructure

- Transition from negative to positive impacts during the established stage:
 - As the share of Intermediate and Advanced AVs increase)
 - Positive results only at high automation levels and penetration rates.
- No change in car vehicle-km travelled, but:
 - No modal shift considered in this use case.
 - Use case 7 does shows the potentially significant increases in vehicle-km travelled.



Use case 2: Gothenburg, SE

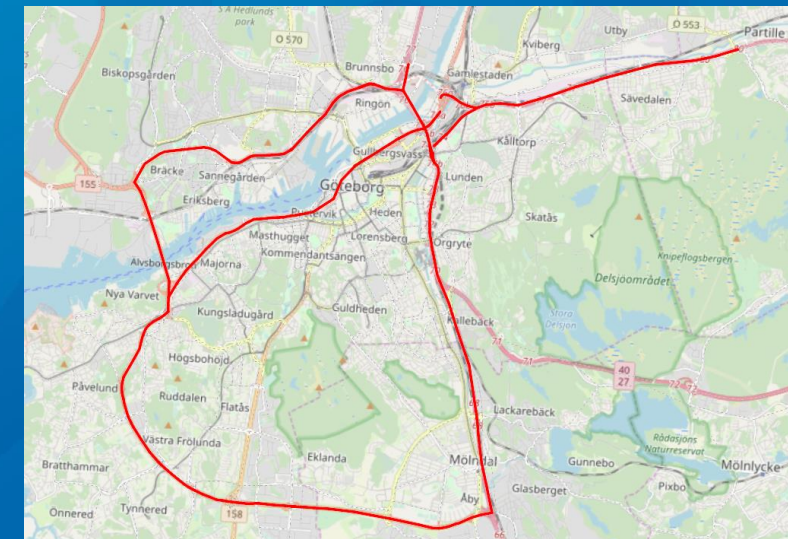
Accessibility during long-term construction works



Macroscopic

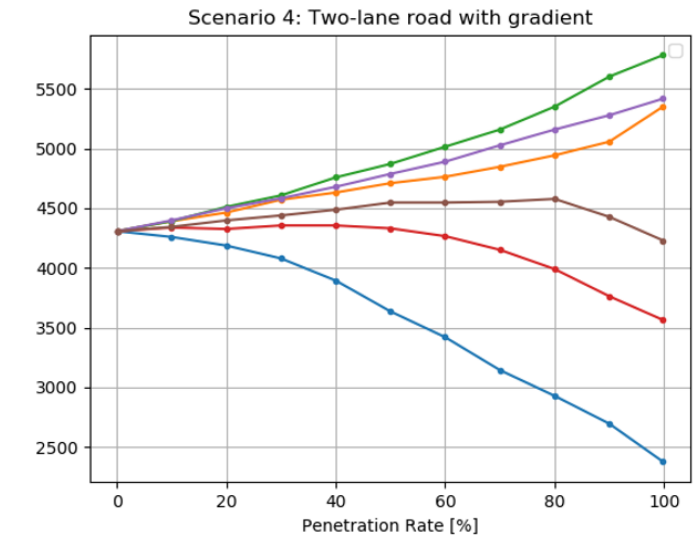
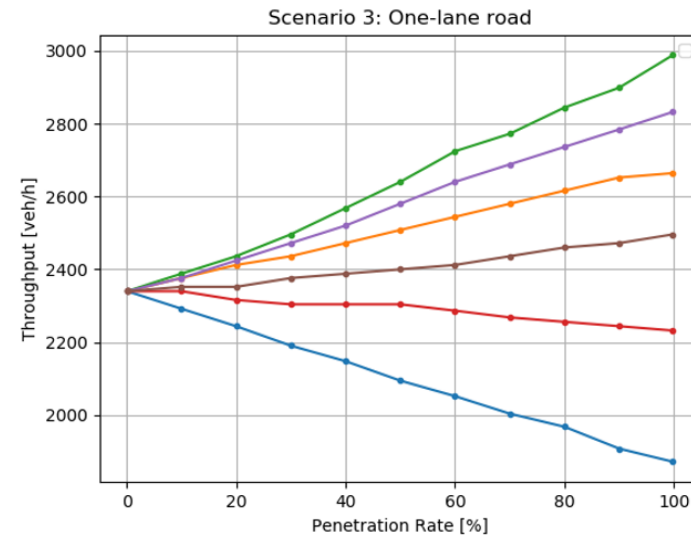
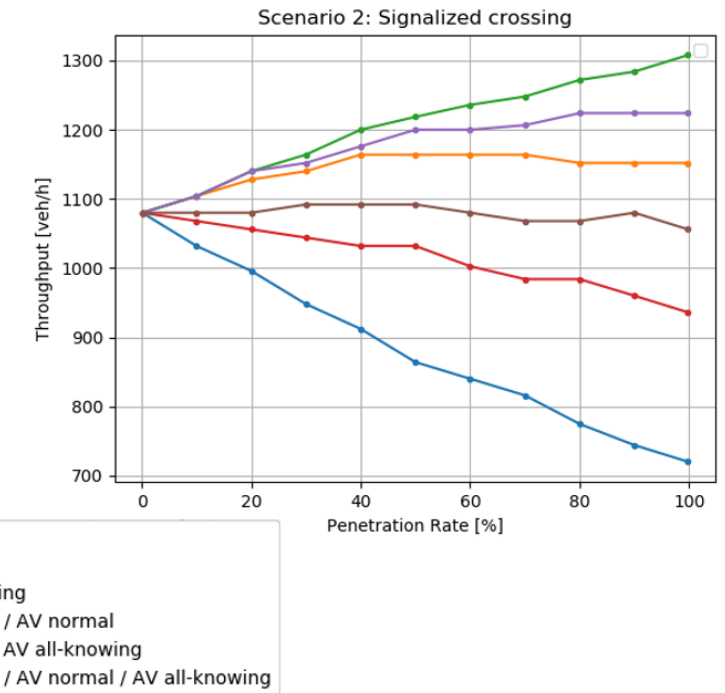
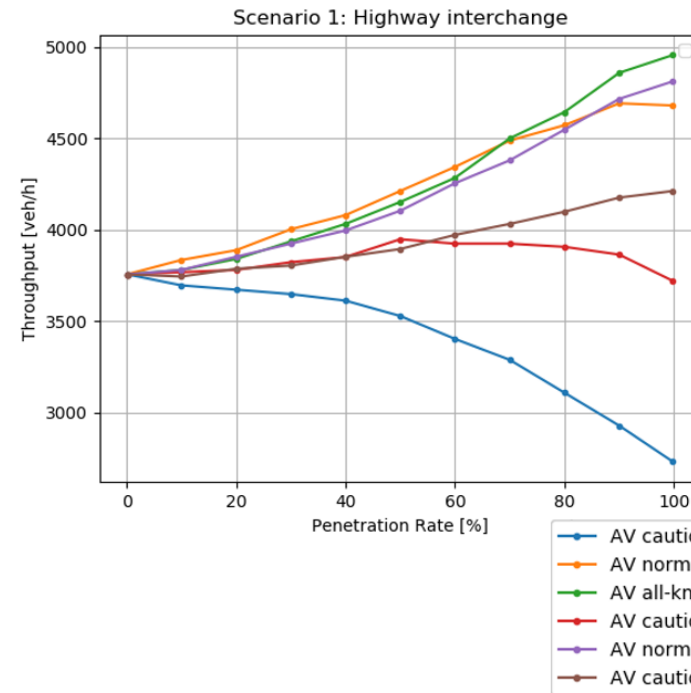
Conclusions: proposed measures

- Measure 1: Two-way AV-only tunnel tube
 - Marginal increase in travel time and delay in the Introductory stage
 - Slight decrease in travel time and delay in the Established stage and somewhat larger effects in the Prevalent stage.
 - Slight decrease in travel time and delay also for CVs – due to route shift of AVs from alternative routes to the tunnel, which free capacity on alternative routes.
- Measure 2: Reserved 'Bus+AV' lane on the motorway network
 - Marginal increase in travel time and delay in the introductory stage
 - No effects on travel time and delay in general for the Established and Prevalent stages
 - Bus lane travel time decrease in Introductory stage but increase in Established and Prevalent stages
 - Introductory: gain for bus but loss for car
 - Established & Prevalent: no gain or loss for either bus or car



General observations

- The 'Cautious' driving logic decreases capacity and implies delays already at initial stages of CoEXistence
- Positive effects only at later stages (Prevalent or Established)
- At network level, Car's modal participation:
 - Lower at introductory stages
 - Higher as AVs become more advanced and common!



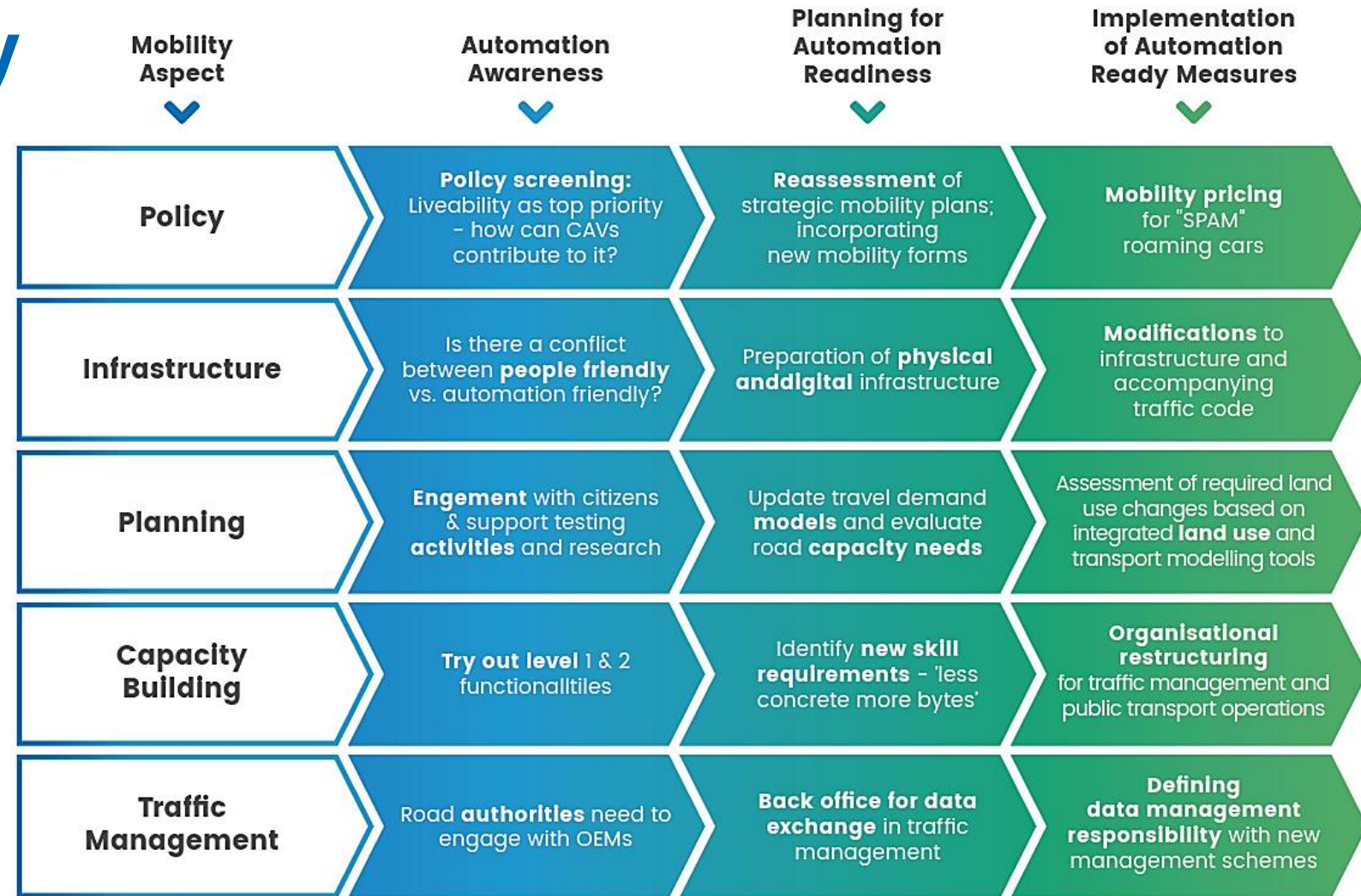
Automation-Ready framework

“Automation-readiness”

The capability of making structured and informed decisions about the deployment of CAVs

Reduce uncertainties through:

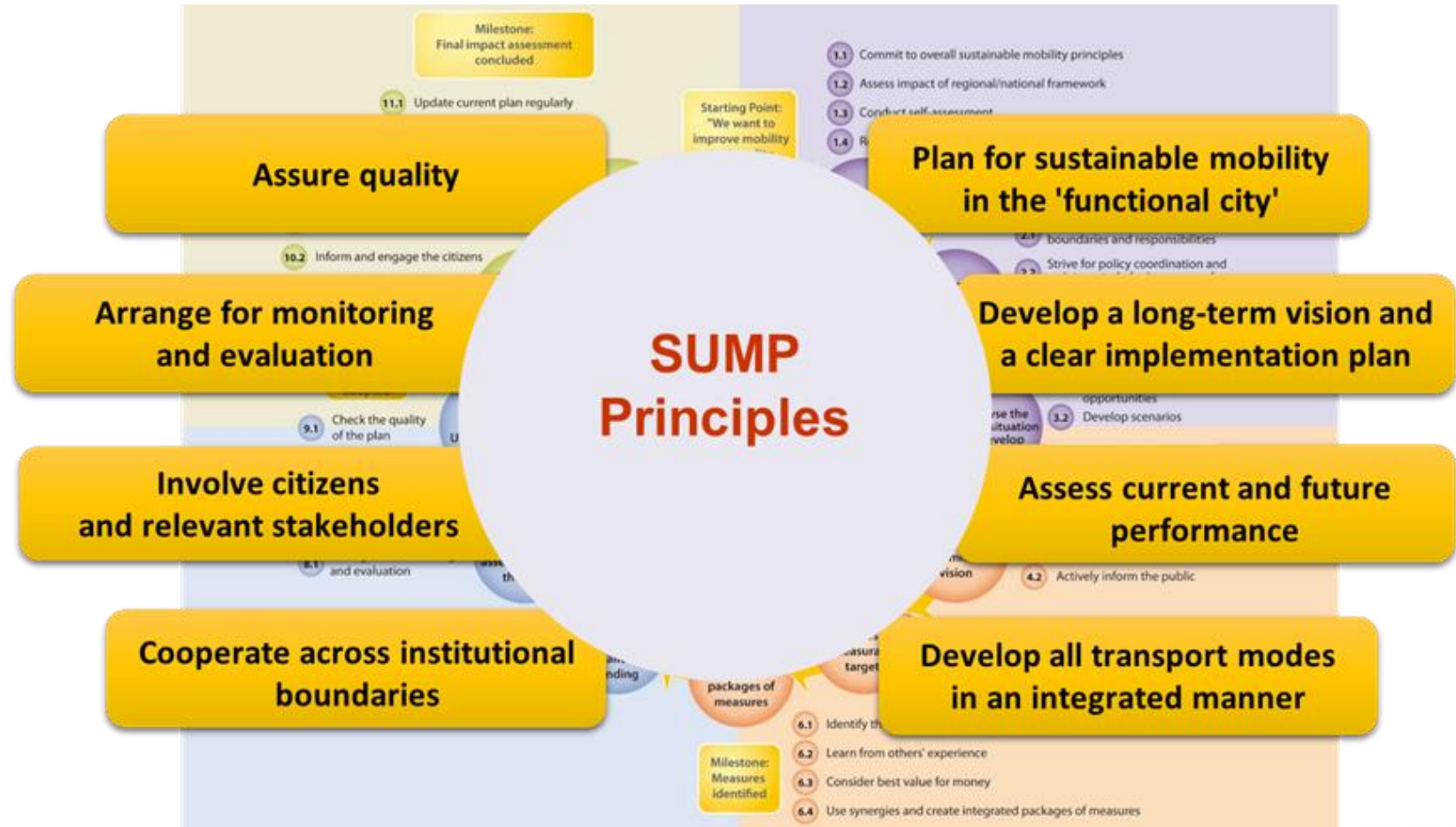
- Guidance on technology, analysis methods, impacts and measures
- Clear-headed and informed decisions about automation
- Automation FAQ for cities



Overview of the phases towards automation-readiness, with examples of measures and relevant questions to guide the analysis

SUMP 2.0 Practitioner's Briefing

How to plan with uncertainties?



How to tackle the imminent disruption to mobility generated by CAV deployment?

- Authorities should look at planning for 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 – spur **flexibility** and create **room for experiments**.

Main achievements & lessons learned

- New features implemented in traffic modelling tool to allow simulation of automated vehicles. But still big responsibility on modeler to define the assumptions (about how vehicle should or will behave).
- Driving logics: much research is ongoing but there are still no fixed rules or standards and high uncertainties.
- Cities' expectation management: findings challenge the positive hype around CAVs- in particular for the transition phase. Learnings are more “how to prepare for planning!”
- All uncertainty requires a structured way of assessing future scenarios. CoEXist delivered the tools for a structured approach (e.g. automation-ready framework).

Main achievements & lessons learned

- All use case simulations show “hell” scenario before “heaven” scenario; transition phase!
- Inserting CAVs in traffic does not necessarily improve efficiency. Depends on penetration rate and driving logic. Higher penetration rates and less cautious (more advanced) CAVs will start to generate some gains.
- Opportunity of modal shift towards integrated PT with automated (shared) fleets; service needs to be affordable (social inclusion)! From “gut feeling” to a structured & informed decision-making!
- Tools developed enable assessment of innovative infrastructure measures, but:
 - Measures tested show mobility improvements mainly for high automation and penetration levels.
 - Should urban road change in the transition towards CCAM and how?
 - How to ensure other modes are not negatively affected by automated decision-making (e.g., light signal)?

Join CoEXist's Final Conference in Milton Keynes!



<https://www.h2020-coexist.eu/events/final-conference/>



References

- Richter, E.; Friedrich, M.; Migl, A.; Hartleb, J. (2019): Integrating ridesharing services with automated vehicles into macroscopic travel demand models, MT-ITS 2019, Krakow, DOI: 10.1109/MTITS.2019.8883315
- Friedrich, M., Sonnleitner, J., Richter, E. (2018): Integrating automated vehicles into macroscopic travel demand models. mobil.TUM 2018. DOI 10.1016/j.trpro.2019.09.060
- Friedrich, M., Hartl, M., Magg, C. (2018): A modeling approach for matching ridesharing trips within macroscopic travel demand models, Springer Transportation November 2018, Volume 45, Issue 6, pp 1639–1653, DOI 10.1007/s11116-018-9957-5
- CoEXist Deliverable 2.7 (2018): AV-ready macroscopic modelling tool, <https://www.h2020-coexist.eu/wp-content/uploads/2018/11/D2.7-AV-ready-macroscopic-modelling-tool.pdf>
- CoEXist Deliverable 2.8 (2018): Guide for the simulation of AVs with a macroscopic modelling tool, <https://www.h2020-coexist.eu/wp-content/uploads/2018/11/D2.8-Guide-for-the-simulation-of-AVs-with-a-macroscopic-modelling-tool.pdf>



References

- Olstam, J and F. Johansson (eds) - D1.4 Scenario specifications for eight use cases, Deliverable 1.4 of the CoEXist project, <https://www.h2020-coexist.eu/wp-content/uploads/2019/10/D1.4-Scenario-specification-for-eight-use-cases-.pdf>
- Olstam, J., Johansson, F., Alessandrini, A., Sukennik, P., Lohmiller, J., Friedrich, M. An approach for handling uncertainties related to behaviour and vehicle mixes in traffic simulation experiments with automated vehicles, working paper under review. Transportation Research: Part C.
- CoEXist: Deliverable 1.1 (2018). Automation-ready framework.
- www.h2020-coexist.eu/wp-content/uploads/2018/12/D1.1-Automation-Ready-Framework-Preliminary-version-1.pdf
- CoEXist (2019). CoEXist Automation-Ready survey – preliminary results available. <https://www.h2020-coexist.eu/coexist-automation-ready-survey-first-results-available/>
- Freemark et al. (2019). Are cities prepared for autonomous vehicles? Planning for technological change by U.S. local governments. Retrieved from https://mobility.mit.edu/sites/default/files/Are%20cities%20prepared%20for%20autonomous%20vehicles_0.pdf



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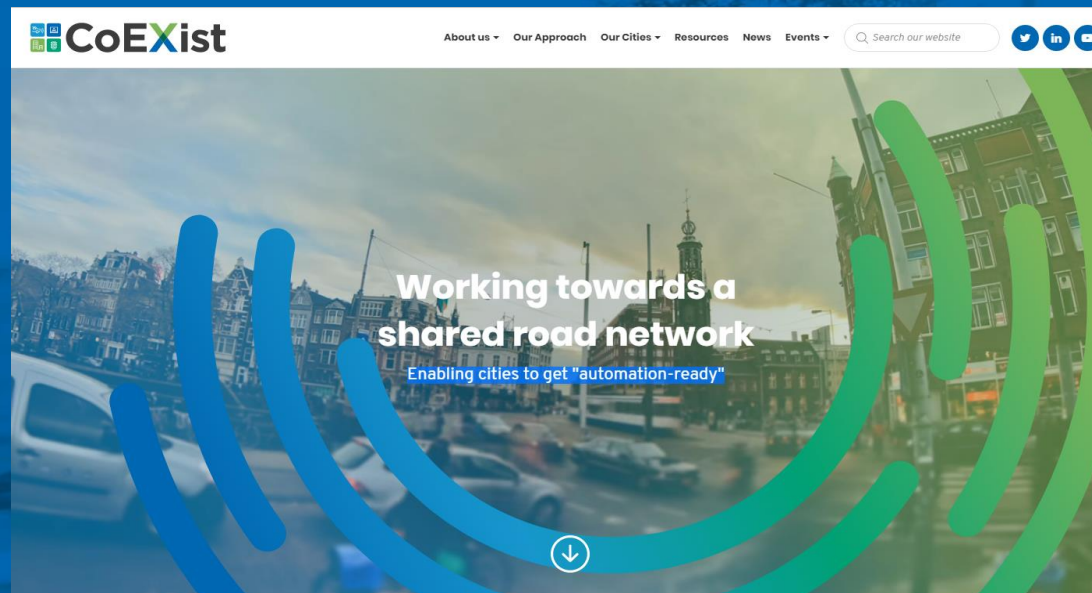


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