D4.2: Technical report on the application of AV-ready modelling tools (incl. input and output data)

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Technical report on the application of the built-in functionalities for the AV-ready macroscopic modelling tool

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1 Introduction

A key goal of the CoEXist project is to enable local road authorities and other urban mobility stakeholders to evaluate the impact of the introduction of connected and automated vehicles (CAVs). One part of achieving this goal is the development of extended traffic models able to model traffic with various mixes of different types of CAVs, as presented in CoEXist deliverables D2.10 / D2.11 (Sukennik, 2020a, Sukennik, 2020b) and D2.7 / D2.8 (Sonnleitner and Friedrich, 2018, Sonnleitner and Friedrich, 2020). The models have been implemented in the PTV traffic modelling software Visum and Vissim. One of the purposes of the eight CoEXist use cases is to test and demonstrate the developed models by applying them to relevant problems.

1.1 Aim

This report presents the results of the application of the extended traffic models to the eight CoEXist use cases. The aim is to provide a self-contained report on each use case, complete with everything from problem formulation, model development, and experimental design, to presentation of simulation results. The background and the development of the baseline models have already been reported in D4.1 but has been revised and is included in this deliverable to provide a self-contained and complete technical report of the modelling of each use case. A much briefer report on the application of the use cases will be given in D4.3 where the tools for assessing the impact of automated vehicles will be applied to the simulation outputs of the use cases, providing high level results and conclusions.

1.2 Structure and context of the report

This is one of several reports concerning the evaluation of impacts that automated vehicles have on traffic and mobility, for the eight CoEXist use cases. There are in total seven deliverables directly related to the evaluation of the use cases:

- D1.3 Use case specifications (Olstam and Johansson, 2018a)
- D1.4 Scenario specifications for eight use cases (Olstam and Johansson, 2018b)
- D3.1: Completed experimental design templates for eight use cases and AV-ready alternative design (Olstam, 2018)
- D4.1 Baseline microscopic and macroscopic models (Liu and Olstam, 2018)
- D4.2 Technical report on the application of AV-ready modelling tools (incl. input and output data)
- D4.3 Technical report on the application of the tool for assessing traffic impacts of automated vehicles (Olstam et al., 2020)
- D3.4 AV-ready hybrid road infrastructure design recommendations
- D4.7 Guidelines: How to become an AV-ready road authority?

These reports include documentation at different stages of the specification and evaluation of the use cases. D1.3 and D1.4 presents the use cases and the scenarios at the planning stage. D3.1 describes the more formalised experimental designs based on the measures and uncertain factors described in D1.3 and D1.4. The deliverable D4.1 describes the development of the traffic models for the current situation without automated vehicles, while this deliverable D4.2 describes the inclusions of the automated vehicles in the traffic model applications for the use cases and the simulation results. D4.2 constitutes a final report for the traffic modelling and includes updated and revised descriptions of the

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steps documented in the four earlier deliverables, hence D1.3, D1.4, D3.1, and D4.1 can be seen as draft versions of different parts of D4.2, as illustrated in Figure 1. Deliverable D4.3 is a complement to D4.2, with presentation of results using the tools for assessing traffic impacts of automated vehicles. Deliverable D3.4 will include conclusions on current road designs and tested measures in the eight use cases focusing on the results and not all the technical details with respect to the traffic modelling. The last deliverable in the bullet list, D4.7, will include summaries of the evaluation of the different use cases from D3.4 and discuss possible implications for the road authorities.

This report starts with a description of the process used to derive and define the use cases (section 2). Section 3 then gives an overview of the modelling and evaluation approach using the automation-ready traffic and transport models developed in CoEXist. Section 0 presents a summary of the eight use cases. Detailed descriptions of the model and results for each of the use cases are attached to the deliverable in form of 8 appended reports one for each use case. In addition to the three macroscopic use cases without additional modes (use case 2 & 7) which were assessed using the modelling technique developed and made available during the project (described in D2.7 and D2.8), a comparison of the results for the macroscopic use case 7 of the final modelling approaches based on volume-delay functions with different versions of the implementation in PTV Visum 18 and 2020 were conducted. This comparison is presented in the appended report Technical report on the application of the built-in functionalities for the AV-ready macroscopic modelling tool. Conclusions and lessons learnt are presented in section 5.

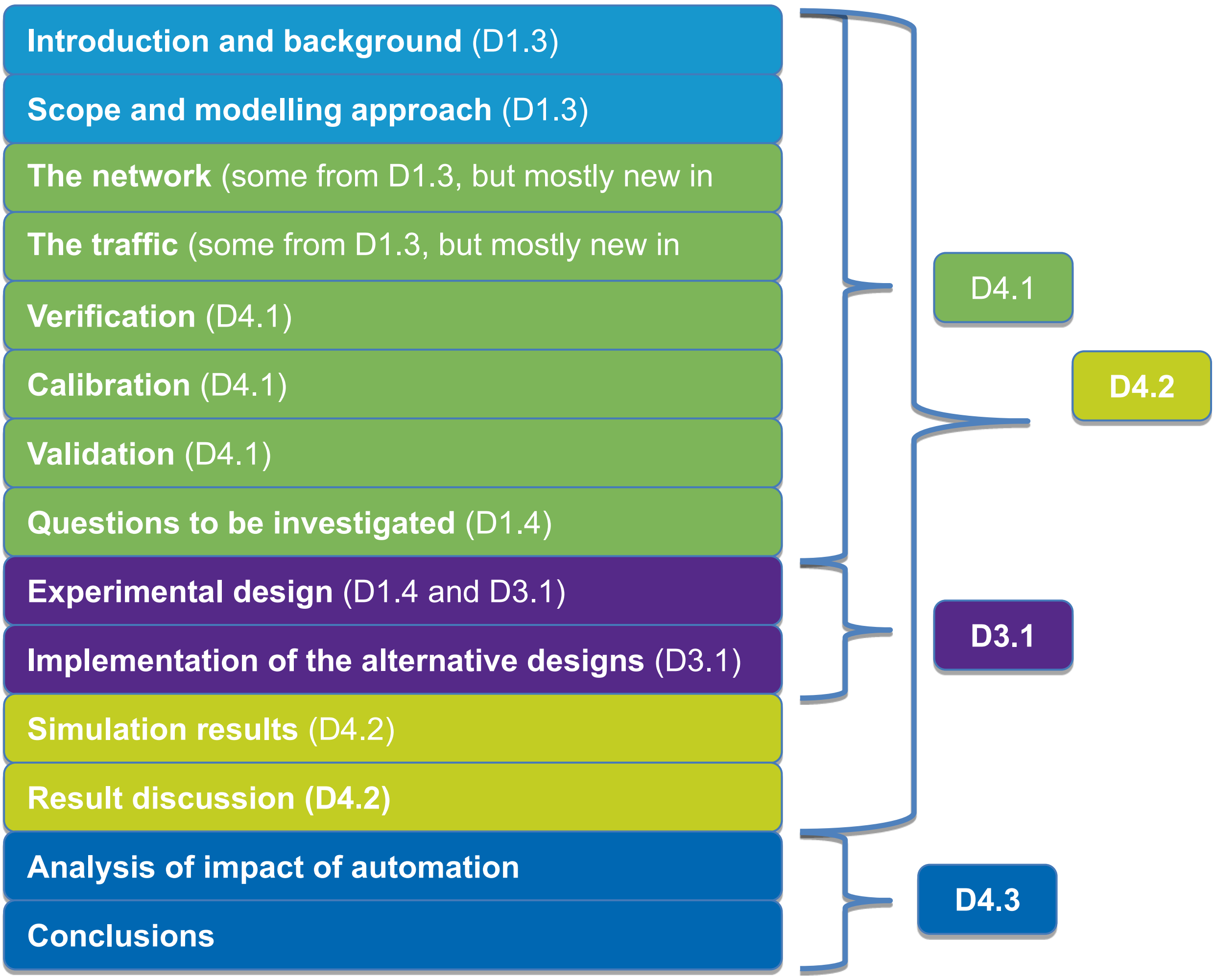

Figure 1 Structure of deliverable D4.2 and the relation to the other use case related deliverables

2 Use case development process

The selection of use cases and specification of the scenarios are based on several discussion rounds, among the CoEXist consortium partners and cities, about the practicality and fit with regards to the specific context of each use case. The first drafts of the use cases were presented in the project proposal. The process for further specification of the use cases and the scenarios is described in Figure 2. To allow for more detailed specification of the use cases that fulfil the aims and ensure consistent description, use case and scenario specification templates were developed and circulated among the cities and their support partners.

The development of each baseline model is to a large extent subject to each responsible partner for the method and data used during the verification-calibration-validation process. Some of the baseline models are developed from scratch while some are further developed on existing models. An ‘experimental design workshop’ took take place 15-16th May 2018 in Gothenburg, Sweden, and the plans and progress of the baseline models were presented and discussed. The results from the workshop

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together with the use case and scenario specifications were then used to guide the development of the baseline model for each use case.

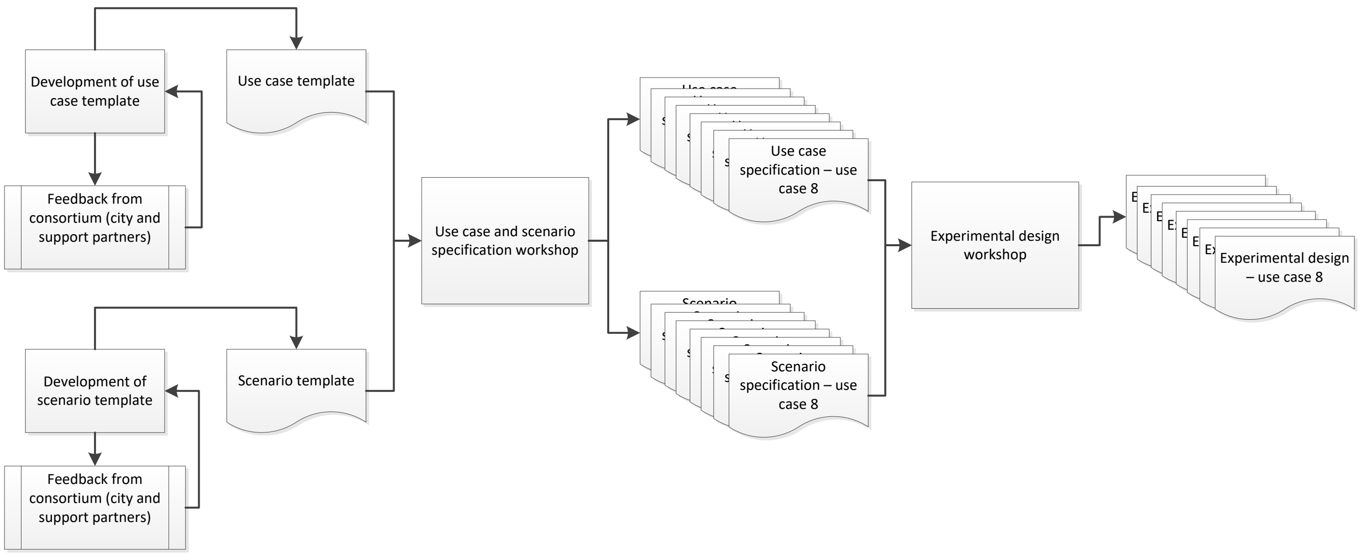

Figure 2 Flowchart describing the different activities in the development of the use cases, scenarios and experimental designs.

3 Modelling and evaluation approach

Since very little is known about how future CAVs will behave, the general modelling approach of the CoEXist project aims at describing a range of possible behaviours to obtain an interval within which it is likely the impact of automated vehicles will be. This is in stark contrast to the common approach of assuming one or a few specific behaviours and evaluate the exact impact the introduction of these specific types of AVs would have.

The behaviours of the automated vehicles are specified by driving logics which are functionally defined, that is, they are specified in terms of how and where they can operate safely, disregarding which technologies that make this possible. The driving logics represents a range of behaviours spanning from the very cautious rail safe driving logic, to the superhuman all-knowing driving logic. The driving logics are presented in D1.4 and can be briefly summarized as

- 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.

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Since it is reasonable to expect that a given CAV will behave differently in different environments, the driving logics are combined to AV-classes by specifying the driving logic a vehicle of an AV class will use on each road type, see D1.4 for details. The AV classes are:

- Basic AV: SAE level 4 capabilities only for one directional traffic environments with physical separation with active modes. The behaviour is in general quite cautious and risk minimizing.
- Intermediate AV: SAE level 4 capabilities in some road environments and driving context. The behaviour at more complicated road environments and driving context is still cautious and risk minimizing while the behaviour at less complicated road environments and driving context can be less cautious and still be safe.
- Advanced AV: SAE level 4 capabilities in most road environments and driving context. The behaviour and its cautiousness vary depending on road environment and driving context.

A goal of the traffic modelling in the CoEXist project is to assess how the impact of automated vehicles 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 discretized into three stages, further described in D1.4:

- Introductory stage: Automated driving has been introduced, but the majority of vehicles are conventional cars. Automated driving is in general significantly constrained by limitations (real or perceived) in the technology.
- Established stage: Automated driving has been established as an important mode in some areas. Conventional driving still dominates some areas due to limitations (real or perceived) in the technology.
- Prevalent stage: Automated driving is the norm, but conventional driving is still present.

The impact of automated vehicles is assessed for each stage with a range of assumptions regarding uncertain parameters to gauge the uncertainty of the predicted impact. The parameters that are varied within each stage is for example penetration rates of various AV classes, traffic volumes and behavioural adaptation of non-automated modes of transport. This results in an interval of likely impacts of automated vehicles for each stage of coexistence.

The microscopic models of the four driving logics is implemented in Vissim by PTV, see D2.11, and used to simulate the future scenarios in the microscopic use cases. This implementation is also used to derive passenger car units for automated vehicles used in the macroscopic modelling by simulating various types of infrastructure with different penetration rates and mixes of CAVs, see D2.7. The passenger car units derived in this way is then implemented in Visum using user-defined volume-delay functions and used to model the future scenarios in the macroscopic use cases.

4 Overview of the use cases

The automation-ready tools developed within the CoEXist project have been used to evaluate the traffic impact of automation for eight diverse use cases in four different cities. For five of the use cases a microscopic traffic model is applied and for three use cases a macroscopic traffic modelling approach is used. Applying traffic models for a specific use case commonly follow a process that include the following steps:

1. formulation of the aims and scope of the study,
2. input data collection,
3. construction of the baseline traffic model,
4. model verification,
5. model calibration,
6. model validation,
7. alternatives analysis and
8. documentation.

This process is also used for the CoEXist use cases and the appendices for each use case follows this structure.

Brief summaries of the use cases are presented below. The detailed descriptions of use cases, the traffic models, the experimental design and the results are presented in the appendices

4.1 Use case 1: Shared space

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 scenario being evaluated 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.

A detailed description of the model and results is available in the appended report: Use case 1 – shared space: Technical report on the application of AV-ready modelling tools (incl. input and output data).

4.2 Use case 2: Accessibility during long-term construction works

A macroscopic Visum model over the Greater Gothenburg utilising the intersection capacity analysis methodology (ICA methodology) and including a method for signal prioritization and weaving movements at on- and off ramps, has been used to investigate how accessibility during long-term construction works is affected by the introduction of automated vehicles.

A detailed description of the model and results is available in the appended report: Use case 2 – Accessibility during long-term construction works: Technical report on the application of AV-ready modelling tools (incl. input and output data)

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4.3 Use case 3: Signalised intersection including pedestrians and cyclists and use case 4: Transition from interurban highway to arterial

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 the signalized intersection and use case 4 on the highway part of the study area. The advanced signal control strategy is represented in Vissim through a connection to an external traffic signal simulator.

A detailed description of the model and results is available in the appended reports: Use case 3 – Signalised intersection including pedestrians and cyclist: Technical report on the application of AV-ready modelling tools (incl. input and output data) and in Use case 4 - Transition from interurban highway to arterial: Technical report on the application of AV-ready modelling tools (incl. input and output data).

4.4 Use case 5: Waiting and drop-off areas for passengers

The Central Milton Keynes (MK) area and its immediate surroundings are implemented in Vissim to investigate the effects of restricting access to the city centre for cars and instead provide vehicle intercept areas at the perimeter of the city centre for transfer to another mode. The requirements for the vehicle intercept areas and the traffic performance of the surrounding infrastructure is investigated as automated vehicles are introduced.

A detailed description of the model and results is available in the appended report: Use case 5 -Waiting and drop-off areas for passengers: Technical report on the application of AV-ready modelling tools (incl. input and output data).

4.5 Use case 6: Priority junction (roundabouts) operation

A microscopic Vissim model of the H3 Monks Way outside of the Milton Keynes city centre has been applied to investigate the traffic impact of automated vehicles on an arterial with priority junctions (roundabouts). The main focus is on how the introduction of automated vehicles affect the congestion at the roundabouts and measures to assist cautious automated vehicles through the roundabout.

A detailed description of the model and results is available in the appended report: Use case 6 – Priority junction (roundabouts) operation: Technical report on the application of AV-ready modelling tools (incl. input and output data).

4.6 Use case 7: Impacts of AV on travel time and mode choice on a network level and Use case 8: Impact of driverless car- and ridesharing services

Both Stuttgart use cases utilise a macroscopic multimodal Visum model for the Stuttgart Region, replicating the trips of the 2.7 million inhabitants of the region split into 1175 zones. In use case 7 the model is used to investigate the impact of automated vehicles on capacity, route choice, and mode choice. Use case 8 aims at providing a better understanding of the impacts that driverless car-sharing systems might have on public transport and traffic volumes, depending on whether the service is private or public, and on the price levels.

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A detailed description of the model and results is available in the appended reports Use case 7 – Impact of CAV on travel time and mode choice on a network level: Technical report on the application of AV-ready modelling tools (incl. input and output data) and in Use case 8 – Impact of driverless car- and ridesharing services: Technical report on the application of AV-ready modelling tools (incl. input and output data).

5 Discussion and lessons learned

This document and its appendices describe the development and application of microscopic and macroscopic models that have been used to assess the impact of the introduction of automated vehicles in the eight CoEXist use cases. These models represent areas with different geographical scales. For instance, the macroscopic models used in use case 7 and 8, cover the whole Stuttgart region including 2.7 million inhabitants while the microscopic model used in use case 3 focuses on a single signalised intersection in Helmond. Private vehicles, freight transport vehicles, public transport, cyclists and pedestrians are included in one or several of the microscopic and macroscopic models, providing a comprehensive assessment for investigating the impact of CAVs.

Through the development and application of the microscopic and macroscopic models, the following experiences can be summarized:

- Some of the baseline models has been under development for a long time and used for various purposes. Therefore, the baseline models are often designed to tackle different challenges with different modelling approaches.
- CAVs are often tested in a future scenario where infrastructures may change from the data used for the verification-calibration-validation process. In this sense, there is no possible way to validate the model outcome of a future scenario without CAVs but with only future infrastructure, since these infrastructures are not present in reality. In that sense, the outcome of the model can be considered more as an assessment of the impact of CAVs rather than prediction of future traffic situation with CAVs.
- The uncertainties introduced by the limitation of modelling approach and level of detail of the model can partially be tackled by using sensitivity analysis. This however inevitably increases the number of scenarios and suffers from the curse of dimensionality.
- As is evident from the presentation of the results of the assessment of the impact of automated vehicles in each use case, the results become rather complex and difficult to present concisely, due to the many uncertainties inherent to the assessment. To facilitate concise and consistent presentation of results, the assessment tool, presented in D3.3 is applied to the simulation output of the use cases and presented in D4.3.
- The new AV-related features included in Visum 2020 increase the possibilities how to model AVs. The revised interface for volume-delay functions (VDF) in static assignments can be used more flexibly. At the same time, runtimes can be reduced, while results remain within the range of model accuracy. The simulation-based dynamic assignment (SBA) requires a lot of input and assumptions, because it works time-dependently. However, SBA offers a large flexibility when modelling AV considering a simplified car-following model. The experiments' results within a simplified road environment correspond to the expectations. Future research may focus on the application of SBA to larger models and a direct comparison to VDF.

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7 Partners

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