# Deliverable 2.3

## Default behavioural parameter sets for Automated Vehicles (AVs)

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# Table of contents




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# 1 Introduction

## 1.1 Understanding the recommendations

This document defines the driving behaviour parameter sets for 4 driving logics that were defined and used within the CoExist project[1]. The behaviour parameter sets are mainly applicable and usable with the microscopic traffic simulation software PTV Vissim. Adjustments to different types of models, in simulation software other than PTV Vissim, can be inferred from the recommendations given here, but caution must be taken especially when the driving behaviour parameters are based on a different type of model (e.g. models apart from Wiedemann).

Recommendations are based on an analysis of empirical data collected in Helmond (the Netherlands), co-simulations results delivered by VEDECOM and several simulation tests done by PTV. More details on the data collection will be available in the deliverable D2.6: technical report on data collection and validation process. Another prerequisite to determining the driving behaviour parameter sets was developing the closed loop connection for co-simulations between the AV control logic of VEDECOM and the AV simulator PreScan from TASS International, which is described in the deliverable D2.2: technical report on connecting CAV control logic and CAV simulator.

### 1.1.1 General recommendation

The sub-chapters “general recommendation” indicate in which direction it is recommended to change default driving parameters’ values (an increase, a reduction or no change of the default value), which are designed for conventional traffic. The strength of the change should correlate with a known information or a reasonable assumption.

### 1.1.2 Recommended numerical values

All numerical values of feature settings (flags to be set on/off) need to be understood as recommended values based on the results of the analysis of the data collection and of the co-simulations undertaken within the context of the CoEXist project. Please note that these data and results do not cover all possible scenarios and the whole complexity of the problem. Thus, different values might be used if another assumption is made or other results/data are available.

## 1.2 PTV Vissim version

All parameters or features mentioned bellow are available starting from PTV Vissim 11 release version (planned release date: end of September 2018). For consortium partners & CoExist purposes, a development version is available since May 2018.

[1] See deliverable D1.4 : Scenario specification for eight uses cases and its appendix A : driving logics

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## 1.3 New features connected to driving behaviour

Besides the recommendations for existing driving behaviour parameters, this document covers also recommendations for new features implemented into PTV Vissim (development powered by the CoEXist project). Description of new developments is covered by deliverable D2.4: PTV Vissim extension – new features and improvements. For an explanation of all new functionalities and also AV-related how-to, a webinar was held on June 21, 2018[2]. An AV-related PTV Vissim guide (D2.5) will be prepared and released in October 2018.

## 1.4 Driving logics

Separate driving parameter sets were defined for each driving logic defined in the CoEXist project[3], namely:

- Rail safe, this driving logic requires besides the appropriate parameters also special modelling approach to be in line with the control logic principles. This driving logic has a deterministic behaviour, that fits quite well to automatically moving machineries as we find in closed environments of ports or factory. It is characterized the presence of a physical lane separation or big lateral distances, a pre-defined path that the vehicles follow, no lane change, no un-signalized intersection and the brick wall stop distance is kept at all time. The modeller need to keep these specificities in mind.
- Cautious, the vehicle respects the road-code and always adopts a safe behaviour. The brick wall distance is always respected, unsignalized intersections and lane changes are possible but the vehicle will keep quite large gaps.
- Normal, very similar to a human driver with the additional capacity of measuring distances and speeds of the surrounding vehicles thanks to its sensor suite.
- All knowing, with perfect perception and prediction leading mainly to smaller gaps for all manoeuvres and situations. A kind of cooperative behaviour is expected.

## 1.5 Cooperation & communication functions

Some implications of simple cooperation & communication functions might be simulated by changing the driving behaviour parameters and appropriate settings in PTV Vissim. For modelling of complex cooperation & communication functions additional actions might be necessary – using one of the available interfaces (COM, drivermodel.dll or drivingsimulator.dll) to mimic complex communication and cooperation strategies.

[2] See in appendix A of D2.4

[3] For a detailed description of the driving logics and their principles see the appendix A of D1.4.

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# 2 Default driving behaviour parameters

## 2.1 New features

The recommended use of all newly developed features is summarised in the table below.

**Table 1 New features and recommended use for AVs**

| | recommended setting for new features | | | |
|---|---|---|---|---|
| driving logic | enforce absolute breaking distance (EABK) | use implicit stochastics | number of interaction vehicles* | increased desired acceleration |
| rail safe | ON | OFF | 1 | 100% |
| cautious | ON | OFF | 1 | 100% |
| normal | OFF | OFF | 1 | 100-110% |
| all knowing | OFF | OFF | >1 | 110% |

* for advanced sensors and/or communicating vehicles choose more than 1 if information from more than one vehicle ahead is available

## 2.2 Following behaviour

This chapter covers the parameters that can be found on the PTV Vissim Tab "Following" and "Car following model" of a driving behaviour set based on the Wiedemann 99 following model. The Wiedemann 74 following model should be used only for very simple AV modelling because of the lower number of adjustable parameters.

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### 2.2.1 General recommendation

**Table 2 General recommendation for the Wiedemann following behaviours**

| | model | parameter** | driving logic | | | |
|---|---|---|---|---|---|---|
| | | | **rail safe** | **cautious** | **normal** | **all knowing** |
| following behaviour | Wiedemann 99 | CC0 – Standstill distance (m) | def | def | def | smaller |
| | | CC1 – Spacing time (s) | def/higher* | def/higher* | def | smaller |
| | | CC2 – Following variation (m) | def/smaller | def/smaller | smaller | smaller |
| | | CC3 – Threshold for entering “following” (s) | def/higher | def/higher | def | def |
| | | CC4 – Negative „following“ threshold (m/s) | Smaller | def/smaller | def/smaller | smaller |
| | | CC5 – Positive „following“ threshold (m/s) | Smaller | def/smaller | def/smaller | smaller |
| | | CC6 – Speed dependency of oscillation ($10^{-4}$ rad/s) | def/smaller | def/smaller | def | smaller |
| | | CC7 – Oscillation acceleration ($m/s^2$) | def/smaller | def/smaller | def/smaller | smaller |
| | | CC8 – Standstill acceleration ($m/s^2$) | Smaller | smaller | def | def |
| | | CC9 – Acceleration at 80 km/h ($m/s^2$) | Smaller | smaller | def | def |
| | W74*** | ax | def | def | def | smaller |
| | | bxadd | def/higher* | def/higher* | def | smaller |
| | | bxmult | def/higher* | def/higher* | def | smaller |

* if EABK[4] is on, brick wall stop distance is guaranteed
** see PTV Vissim manual for a detailed description
*** Wiedemann 74, might be used for very simple models only

[4] EABK = enforce absolute breaking distance (new feature released in PTV Vissim 11)

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### 2.2.2 Recommended numerical values

**Table 3 Numerical recommendation for the Wiedemann following behaviour**

| | model | parameter** | driving logic: rail safe | cautious | normal | all knowing | def |
|---|---|---|---|---|---|---|---|
| following behaviour | Wiedemann 99 | CC0 – Standstill distance (m) | 1.5 | 1.5 | 1.5 | 1 | 1.5 |
| | | CC1 – Spacing time (s) | 1.5* | 1.5* | 0.9 | 0.6 | 0.9 |
| | | CC2 – Following variation (m) | 0 | 0 | 0 | 0 | 4 |
| | | CC3 – Threshold for entering "following" (s) | -10 | -10 | -8 | -6 | -8 |
| | | CC4 – Negative „following“ threshold (m/s) | -0.1 | -0.1 | -0.1 | -0.1 | -0.35 |
| | | CC5 – Positive „following“ threshold (m/s) | 0.1 | 0.1 | 0.1 | 0.1 | 0.35 |
| | | CC6 – Speed dependency of oscillation ($10^{-4}$ rad/s) | 0 | 0 | 0 | 0 | 11.44 |
| | | CC7 – Oscillation acceleration ($m/s^2$) | 0.1 | 0.1 | 0.1 | 0.1 | 0.25 |
| | | CC8 – Standstill acceleration ($m/s^2$) | 2 | 3 | 3.5 | 4 | 3.5 |
| | | CC9 – Acceleration at 80 km/h ($m/s^2$) | 1.2 | 1.2 | 1.5 | 2 | 1.5 |
| | W74*** | ax | 2 | 2 | 2 | 1 | 2 |
| | | bxadd | 2* | 2* | 2 | 1.5 | 2 |
| | | bxmult | 3* | 3* | 3 | 2 | 3 |

* if EABK[1] is on, brick wall stop distance is guaranteed
** see PTV Vissim manual for detailed description
*** might be used for very simple models only

## 2.3 Lane changing behaviour

This chapter covers the parameters that can be found on the PTV Vissim Tab "Lane Change" controlling the lane changing behaviour.

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### 2.3.1 General recommendation

**Table 4 General recommendation for lane changing behaviour**

| | driving logic | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **rail safe** | | **cautious**** | | **normal** | | **all knowing** | |
| parameter for necessary lane change* | own | trailing vehicle | own | trailing vehicle | own | trailing vehicle | own | trailing vehicle |
| maximum deceleration | n.a. | n.a. | smaller/ def | smaller/ def | def | smaller/ def | def | higher/ def |
| - 1 m/s per distance | n.a. | n.a. | smaller/ def | smaller/ def | def | def | def | smaller/ def |
| accepted deceleration | n.a. | n.a. | smaller/ def | smaller/ def | def | def | def | higher/ def |

*necessary lane change means a lane change which is necessary in order to follow a defined route (it is not overtaking because of higher own desired speed)

** EABD (enforce absolute breaking distance) must be on

n.a. = not applicable

**Table 5 General recommendation for lane changing behaviour functionalities**

| | driving logic | | | |
|---|---|---|---|---|
| behavioral functionality | **rail safe** | **cautious**** | **normal** | **all knowing** |
| Advanced merging* | n.a. | on***/off | on*** | on |
| Cooperative lane change* | n.a. | on***/off | on*** | on |
| Safety distance reduction factor | n.a. | higher+EABD | def/smaller | def/smaller |
| min. headway (front/rear) | n.a. | higher | def | def |
| max. deceleration for cooperative braking | n.a. | smaller*** | smaller***/def | def |

*depends on technical equipment and implemented connectivity & cooperation functions

** EABD (enforce absolute breaking distance) must be on

*** If the AV cannot detect that the other vehicle wants to change lanes, the value should be off/zero

n.a. = not applicable

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### 2.3.2 Recommended numerical values

**Table 6 Numerical recommendation for lane changing behaviour**

| | driving logic | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **rail safe** | | **cautious**** | | **normal** | | **all knowing** | | **def** | |
| parameter for necessary lane change* | own | trailing vehicle | own | trailing vehicle | own | trailing vehicle | own | trailing vehicle | own | trailing vehicle |
| maximum deceleration | n.a. | n.a. | -3.5 | -2.5 | -4 | -3 | -4 | -4 | -4 | -3 |
| - 1 m/s per distance | n.a. | n.a. | 80 | 80 | 100 | 100 | 100 | 100 | 100 | 100 |
| accepted deceleration | n.a. | n.a. | -1 | -1 | -1 | -1 | -1 | -1.5 | -1 | -1 |

*necessary lane change means a lane change which is necessary in order to follow a defined route (it is not overtaking because of higher own desired speed)

** EABD (enforce absolute breaking distance) must be on

n.a. = not applicable

**Table 7 Numerical recommendation for lane changing behaviour functionalities**

| | driving logic | | | | |
|---|---|---|---|---|---|
| behavioral functionality | **rail safe** | **cautious**** | **normal** | **all knowing** | **def** |
| Advanced merging* | n.a. | on***/off | on*** | on | on |
| Cooperative lane change* | n.a. | on***/off | on*** | on | off |
| Safety distance reduction factor | n.a. | 1+EABD | 0.6 | 0.5 | 0.6 |
| min. headway (front/rear) | n.a. | 1 | 0.5 | 0.5 | 0.5 |
| max. deceleration for cooperative braking | n.a. | -2.5 | -3 | -6 | -3 |

*necessary lane change means a lane change which is necessary in order to follow a defined route (it is not overtaking because of higher own desired speed)

** EABD (enforce absolute breaking distance) must be on; n.a. = not applicable

## 2.4 Lateral behaviour

Setting in lateral behaviour allows to set minimum lateral distances to other vehicle classes individually. Due to the lack of empirical or reasonable data, a recommendation cannot be given. Hence, the modeller needs to decide which assumption he/she wants to take into account in lateral behaviour according to the use case – e.g. it is possible to specify higher lateral distance when the vehicle is overtaking a cyclist and lower lateral distance when a CAV is overtaking another CAV.

## 2.5 Signal control behaviour

This chapter covers the parameters that can be found on the PTV Vissim Tab "Signal Control" controlling the reactions on signals and the behaviours when approaching a signal.

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### 2.5.1 General recommendation

**Table 8 General recommendation for signal control behaviour**

| attribute | driving logic | | | |
|---|---|---|---|---|
| | **rail safe*** | **cautious**** | **normal** | **all knowing** |
| behaviour at amber signal | continuous check | continuous check | one decision*** | one decision |
| behaviour at red/amber signal | stop | stop | stop/go | stop/go |
| reaction time distribution | - | - | - | - |
| reduced safety distance factor | higher+EABD | higher+EABD | def | def/lower |
| reduced safety start upstream of stop line | lower/def | lower/def | def | def/higher |
| reduced safety end upstream of stop line | lower/def | lower/def | Def | def/higher |

*only protected phase possible in AV-certified environment

** probably protected phases only, EABD must be on

*** requires that the AV can remember that it has made a decision for that particular signal head already, else: continuous check

### 2.5.2 Recommended numerical values

**Table 9 Numerical recommendation for signal control behaviour**

| attribute | driving logic | | | | |
|---|---|---|---|---|---|
| | **rail safe*** | **cautious**** | **normal** | **all knowing** | **def** |
| behavior at amber signal | continuous check | continuous check | one decision*** | one decision | cont. Check |
| behavior at red/amber signal | stop | stop | stop | stop | go |
| reaction time distribution | - | - | - | - | - |
| reduced safety distance factor | 1 | 1 | 1 | 1 | 0.6 |
| reduced safety start upstream of stop line | 100 | 100 | 100 | 100 | 100 |
| reduced safety end upstream of stop line | 100 | 100 | 100 | 100 | 100 |

*only protected phase possible in AV-certified environment

** probably protected phases only, EABD must be on

*** requires that the AV can remember that it has made a decision for that particular signal head already, else: continuous check

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# 3 Import of driving behaviour parameters

Currently, all recommended parameter values can be entered into a Vissim model manually, using copy/paste functionality or imported from another PTV Vissim model file. For comfortable import of all parameters at once, a PTV Vissim file was created and is available to all project partners. In the future, all settings may become a part of Vissim standard installation and/or an example delivered with PTV Vissim (= available for all users).

# 4 Future changes

Automated driving is developing fast and it is difficult to foresee in which direction. Thus, the recommended values might be subject to change in the future. The GUI of PTV Vissim and the way it is developed and structured allow the user to work with a wide spectrum of assumptions and to calibrate the model with the newest data available.

The proposed driving parameter values will be revised after getting the feedback from the CoEXist partner cities Gothenburg, Helmond, Milton Keynes and Stuttgart in work package 4, where several use cases will be modelled.

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