CoEXist

Deliverable 2.10

PTV Vissim extension – new features and improvements – final version

Version: 2.0
Date: 14.04.20
Author: Peter Sukennik, PTV Group

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 723201

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2.0	14.04.2020	Peter Sukennik (PTV Group)	D2.4 completed with: • Built-in platooning feature • Lane-specific driving behaviour

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2.0	14.04.2020	Charlotte Fléchon (PTV Group)	Review

Table of contents

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1 Introduction

This document describes new automated vehicle (AV) related features and improvements specifically in PTV Vissim software developed within the CoEXist project. This is an updated version of the deliverable D2.4 "*Vissim extension – new features and improvements*".

1.1 PTV Vissim version

All parameters or features mentioned below are available since PTV Vissim 11 release version (release date: October 2018) with the exception of the platooning feature (implemented into Vissim 2020, released in October 2019). Most of the API (application programming interface) improvements are available in PTV Vissim 10 version already. For consortium partners & CoEXist purposes, a development version was available since May 2018. A beta version of Vissim 11, available for all users with a valid Vissim 10 license, has been released at the beginning of August 2018.

1.2 Knowledge transfer

For an explanation of all new functionalities and AV-related how-to, following activities have been performed:

- A webinar was held on 21th June 2018. The slides of the webinar are in appendix A of this document. The recording of the webinar is available on YouTube: https://www.youtube.com/watch?v=C_bouqPNSw4
- An AV-related PTV Vissim guide was prepared in October 2018 (D2.5 "Guide for the simulation of AVs with microscopic modelling tool")
- An updated PTV Vissim manual was available (most of it) for the beta release of Vissim 11 (August 2018), a full update was available with the release version of PTV Vissim 11 (end of September 2018).
- A second webinar was held August 10, 2018 for American time zones within the US PTV Talks series and available online: https://ptvtraffic.us/resources/ptvtalks-coexist/
- An updated PTV Vissim manual was available with the release version of PTV Vissim 2020 (October 2019).
- A third webinar aimed on the platooning feature was held on 11th November 2019 and available online: https://www.youtube.com/watch?v=Gbht_gZZHM8.
- A second edition of the AV-related PTV Vissim guide was prepared in February 2020 (D2.11 "*Guide for the simulation of AVs with microscopic modelling tool - final*")).
- A fourth webinar was held on March 12, 2020 for American time zones within the US PTV Talks series and available online: https://ptvtraffic.us/resources/coexist-2/.
- An online workshop was help within the CoEXist final event (online) on 26th March 2020 for registered participants and now available online: https://www.youtube.com/watch?v=HL-NPQNsJV8.

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1.3 Driving logics

How to use individual features in combination with the driving logics[1] used within the CoEXist project is described in deliverable D2.3. This document describes what was developed and for what purpose.

[1] See D1.4 "*Scenario specification for 8 use cases*" and its appendix A

1.4 Cooperation & communication functions of AVs

Some implications of simple cooperation & communication functions of AVs might be simulated by using new features 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 API improvements

PTV Vissim offers three APIs. Two of them, described below, have been improved significantly. APIs can be used for:

- Simulating vehicles with own algorithms within PTV Vissim
- Connecting & exchanging information with an external simulator (e.g. a sensor simulator)
- Simulating communication & cooperation strategies or any other feature which is not directly available in the GUI of PTV Vissim

API are widely used by car manufacturers and researchers who are developing their own control algorithms. The use of API requires programming skills.

The full description of both mentioned PTV Vissim interfaces can be found in the documents delivered within PTV Vissim installation (see Appendix 1 and 2 of D2.2 “PTV Vissim API - Driver Model Interface.pdf“ and “PTV Vissim API - Driving Simulator.pdf Interface”).

2.1 Drivermodel.dll

The External Driver Model DLL Interface of Vissim provides the option to replace the internal driving behaviour by a fully user-defined behaviour for some or all vehicles in a simulation run. The user-defined algorithm must be implemented in a DLL written in C/C++ which contains specific functions (as specified below). During a simulation run, Vissim calls the DLL code for each affected vehicle in each simulation time step to determine the behaviour of the vehicle. Vissim passes the current state of the vehicle and its surroundings to the DLL and the DLL computes the acceleration / deceleration of the vehicle and the lateral behaviour (mainly for lane changes) and passes the updated state of the vehicle back to Vissim.

The external driver model can be activated for each vehicle type separately in the dialog box “Vehicle Type” by checking the checkbox "Use external driver model” on the tab page “External Driver Model" and selecting a driver model DLL file and optionally a parameter file to be used. If this option is checked, the driving behaviour of all vehicles of this vehicle type will be calculated by the selected DLL. A subdirectory DriverModelData\ must exist in the directory of vissim.exe in order to avoid a warning message when Vissim is started.

The following improvements have been implemented:

- External driver model DLLs may be used now in multithreaded simulation runs if all DLLs confirm that they support multithreading (unless there is only one externally controlled vehicle or all

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externally controlled vehicles are on the same link, the DLL needs to be programmed accordingly, of course).

- If the DLL requests it, Vissim sends the data of all nearby vehicles that the ego vehicle sees according to the current driving behaviour (min./max. look ahead and look back distances, number of observed vehicles) instead of at most 2 for each upstream and downstream per lane.
- User-defined vehicle attribute values can be passed to the DLL and can be modified by the DLL.
- World coordinates of the front end and rear end of nearby vehicles are passed from Vissim to the DriverModel.DLL as well.
- The polyline of the current lane of the ego vehicle (along its route/path, within the visibility distance) is passed to the DLL as well.

2.2 Drivingsimulator.dll

The PTV Vissim add-on module "Driving Simulator Interface" allows to connect Vissim to a driving (cycling, walking) simulator (DS). That DS can either be a simulator hardware used by a human or a piece of software representing the algorithms of a CAV (or multiple CAVs).

Vissim provides the surrounding traffic (vehicles, bicycles, pedestrians) to be visualized in the DS, and the DS passes back the current position and orientation of the simulator vehicle(s) (bicycle(s) / pedestrian(s)). The vehicles and pedestrians in the Vissim network react to this simulator data as to all other vehicles and pedestrians in the microscopic simulation model. In addition, Vissim passes traffic signal states to the DS for visualization, and the DS can set detectors in Vissim explicitly in order to affect the signalization.

The DS does not need to know the Vissim data model where the network is modelled from links, connectors, areas, ramps and obstacles. The DS needs to have its own world model (for simulation and visualization). As all vehicle and pedestrian positions are exchanged in cartesian world coordinates (x/y/z), the DS must be able to provide/use such coordinates, and the coordinates of the networks on both sides (Vissim / DS) must match precisely.

The following improvements have been implemented:

- Automatic interpolation of Vissim vehicle/pedestrian world coordinates, orientations and speeds between Vissim time steps if the simulator informs Vissim about a higher frame rate than the Vissim simulation resolution in the call of VISSIM_Connect().
- Optionally, simulator pedestrians can be passed to Vissim now. The pedestrian type for those needs to be selected in the network settings on the new tab page "Driving simulator". The checkbox for activation of the driving simulator interface and the selection box for the vehicle type for simulator vehicles have been moved there as well.
- The maximum number of objects of each type to be exchanged between the simulator and Vissim can be set by the simulator in the call of VISSIM_Connect().
- The simulator can pass a maximum visibility radius to Vissim in the call of VISSIM_Connect(). Vissim vehicles and pedestrians will be passed to the simulator only if they are inside of this radius from the center of the front end of a simulator vehicle or pedestrian.

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3 New features

3.1 Enforce absolute braking distance

Idea: the vehicle can stop safely anytime (without a crash), even if the leading vehicle stops instantly ("turns into brick wall"). This ensures that the brick wall stop distance is always kept.

It has implications for:

- Following behaviour
- Lane change behaviour
- Gap acceptance at intersections (conflict areas only)

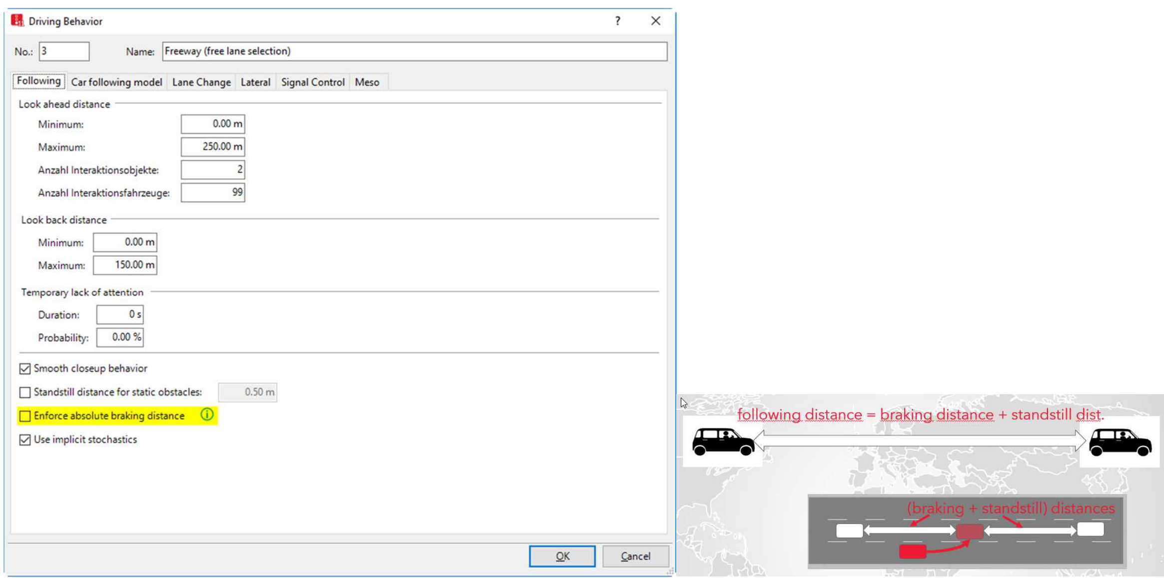

Figure 1 Enforce absolute braking distance dialog (left) and an illustration (right)

3.2 Use implicit stochastics

Idea: the stochastic imperfection of human driving is replaced by deterministic machines & computers. If this attribute is false, a deterministic instead of a stochastically distributed value is used. Affected are the values that:

- cannot be influenced by user e.g. via an adjustable distribution
- are expected to be unaffected by human perception in AVs.

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CoEXist

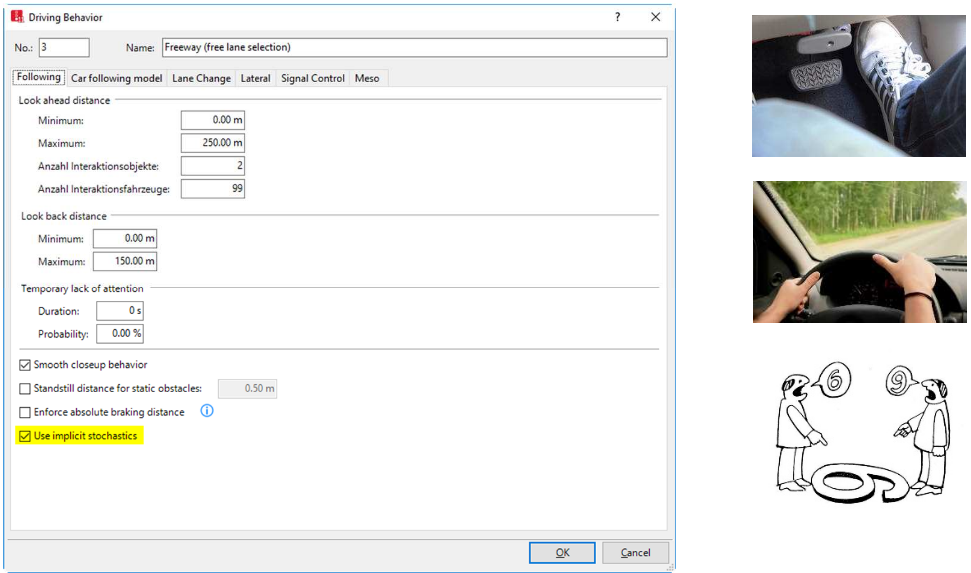

Figure 2 Use implicit stochastics dialog (left) and illustrations (right)

3.3 Class dependent safety distance in following behaviour

Idea: the headway to the followed vehicle depends on the followed vehicle class.

This allows to set different following distances to conventional vehicles, automated vehicles, connected and automated vehicles, cyclists etc.

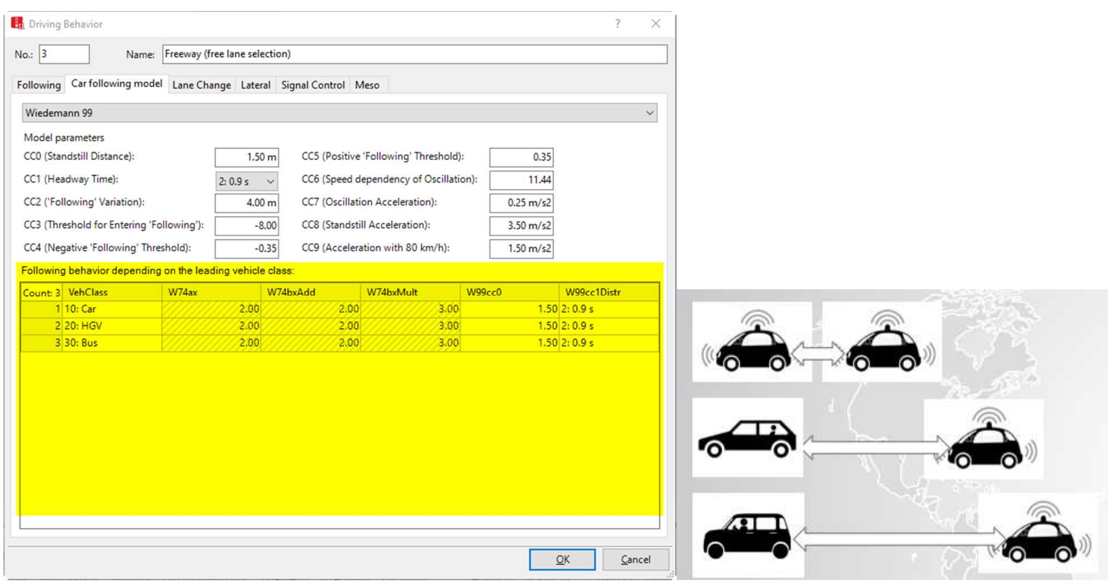

Figure 3 Vehicle class dependency in the dialog (left) and an illustration (right)

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3.4 Number of interaction objects & vehicles

Idea: automated vehicles can see the signals ahead, but only one (or two…) vehicle in front of itself because the sensors cannot see through the leading vehicle.

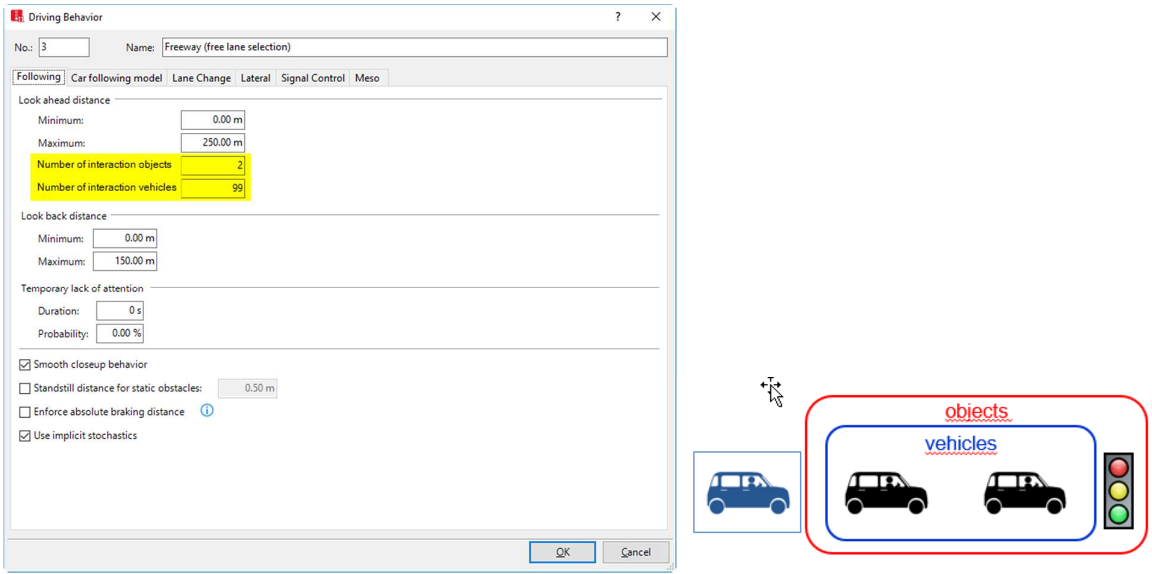

Figure 4 Number of interaction objects & vehicles in the dialog (left) and an illustration (right)

3.5 OpenDrive import

OPEN DRIVE = open file format for the logical description of road networks. It was developed and is being maintained by a team of simulation professionals with large support from the simulation industry. Its first public appearance was on January 31, 2006. This feature allows to read opendrive database and create a network in PTV Vissim.

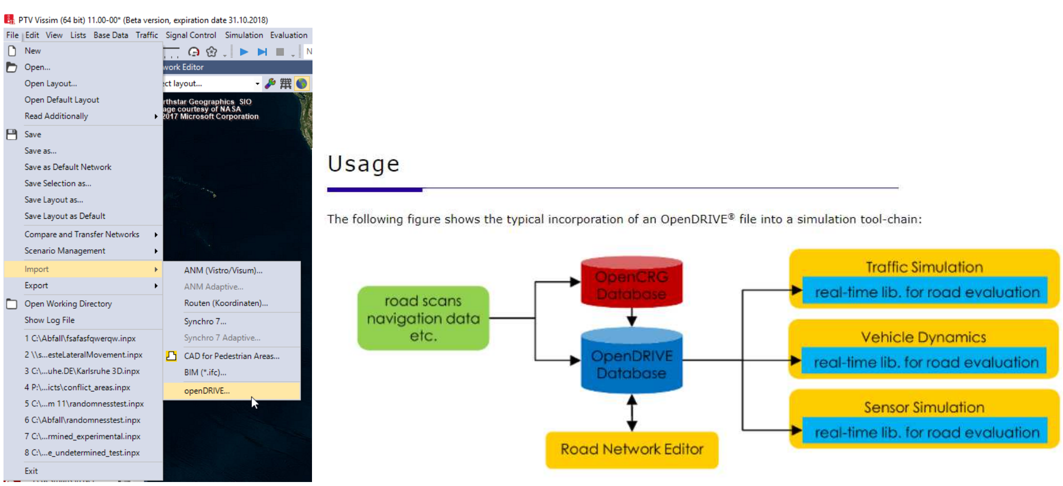

Figure 5 OpenDrive import in the menu and the typical usage of open drive (source: http://www.opendrive.org/)

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3.6 Consider vehicles in dynamic potential

This feature improves the interaction between vehicles and pedestrians in crossing conflicts (e.g. on shared space areas). The pedestrians are able to find and use gaps between standing or slowly moving vehicles dynamically, so their behaviour is more intelligent and closer to the real behaviour.

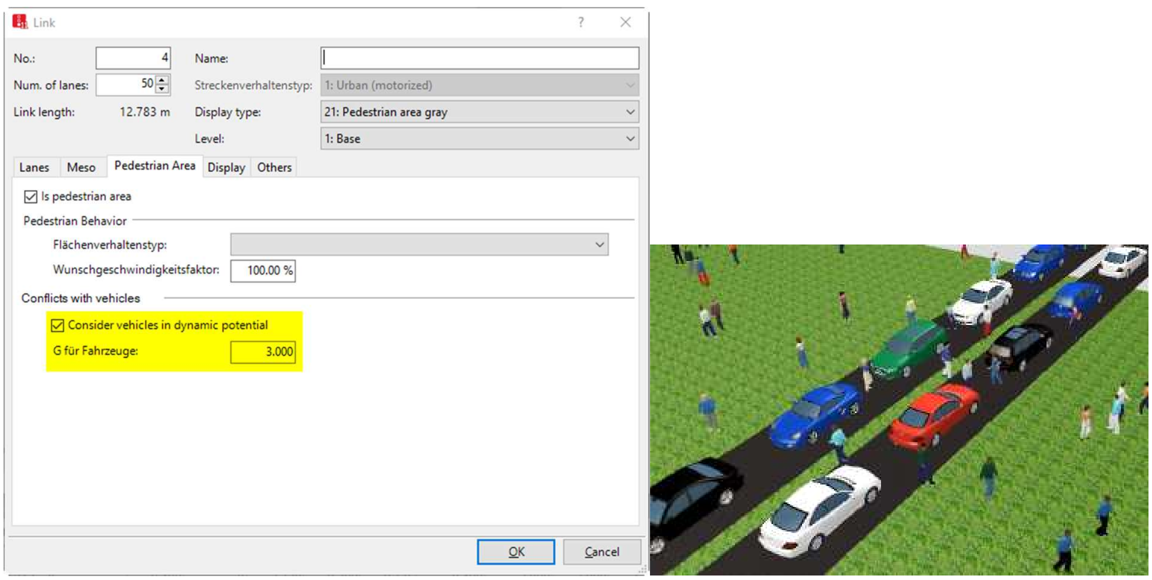

Figure 6 Consider vehicles in dynamic potential in the dialog (left) and an illustration (right)

3.7 Zero passengers

Idea: Simply to allow “empty trips” for future autonomous vehicles (SAE automation level 4 & 5).

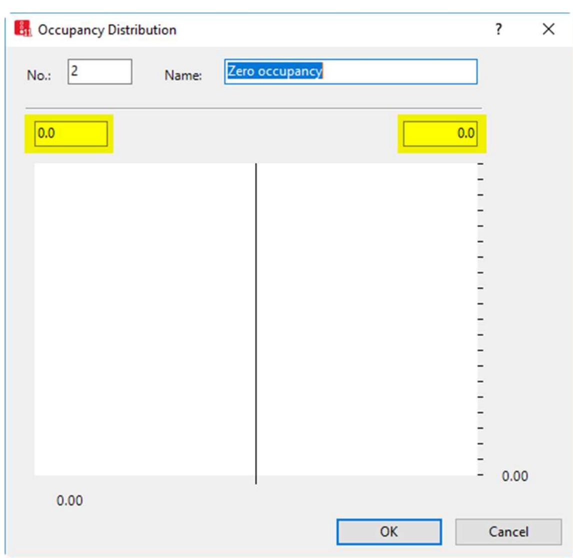

Figure 7 Zero passengers in the dialog

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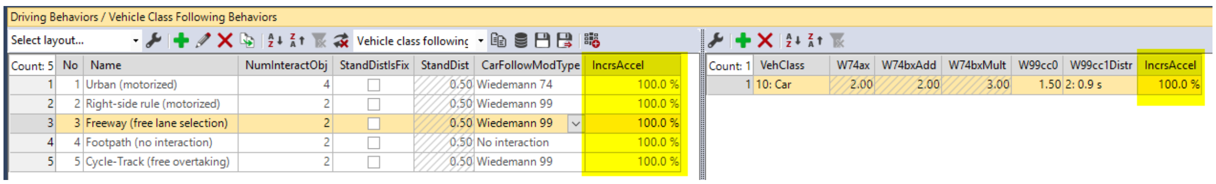
3.8 Increased acceleration in following possible

This new parameter allows to set higher acceleration in following process in order to “stay in touch” when the speed of the leading vehicle increases significantly. The ability to keep close following distance without big losses when leading vehicle accelerates was observed on the test track in Helmond (described in D2.6 Technical report on data collection and validation process). To mimic such behaviour in Vissim, this parameter can be set to value above 100% for specific vehicle class and also in dependency on leading vehicle class.


Driving Behaviors / Vehicle Class Following Behaviors

Select layout... Vehicle class following

Count: 5	No	Name	NumInteractObj	StandDistIsFix	StandDist	CarFollowModType	IncrsAccel
1	1	Urban (motorized)	4	☐	0.50	Wiedemann 74	100.0 %
2	2	Right-side rule (motorized)	2	☐	0.50	Wiedemann 99	100.0 %
3	3	Freeway (free lane selection)	2	☐	0.50	Wiedemann 99	100.0 %
4	4	Footpath (no interaction)	2	☐	0.50	No interaction	100.0 %
5	5	Cycle-Track (free overtaking)	2	☐	0.50	Wiedemann 99	100.0 %

Count: 1	VehClass	W74ax	W74bxAdd	W74bxMult	W99cc0	W99cc1Distr	IncrsAccel
1	10: Car	2.00	2.00	3.00	1.50	2: 0.9 s	100.0 %

Figure 8 Increased acceleration in the list & coupled list

3.9 Labels for vehicles

This feature allows to show any vehicle attribute as a vehicle label which is moving with the vehicle during 2D visualisation. This is useful for debugging or analysing the model, showing results etc.

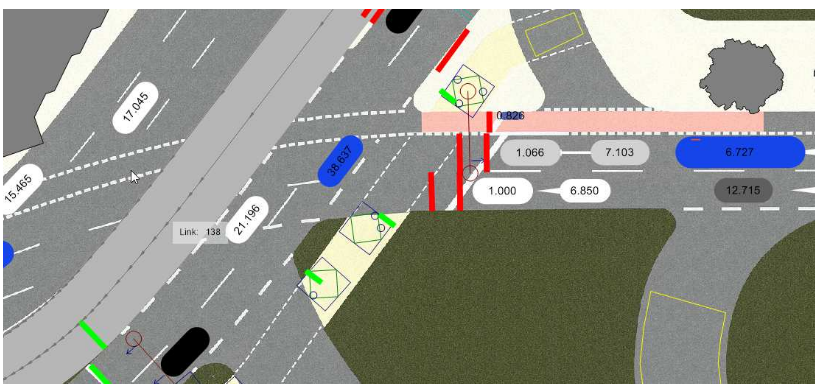


Figure 9 Example of vehicle label showing following distance

3.10 Built-in platooning feature

Simplified platooning functionality configurable through PTV Vissim GUI has been developed and implemented into Vissim 2020 (released in October 2019). Platoon represents connected vehicles traveling very closely & safely together, also at high speeds. This feature in Vissim is suitable for evaluating the overall effects of platooning on the network. However, this feature is not suitable for obtaining specific vehicle data within the platoon (vehicle dynamics), for example, the calculated vehicle emissions of vehicles inside the platoon.

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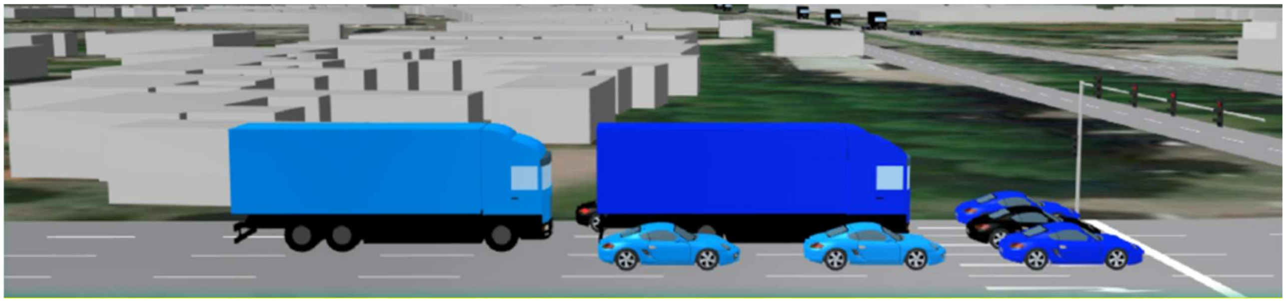

Figure 10 Vehicle in a platoon (dark blue = platoon leader, light blue = platoon member, black = not in a platoon)

Platooning feature can be activated on the tab “Autonomous driving” for each driving behaviour. This feature offers five parameters which are accessible through the dialog (see Figure 11**Fehler! Verweisquelle konnte nicht gefunden werden.**) or the list of driving behaviour. Because these parameters are part of a driving behaviour, they can change from one link or lane to another. That means a vehicle can use during the journey through the network different values for platooning parameters, because every link and every lane can use a specific link behaviour type.

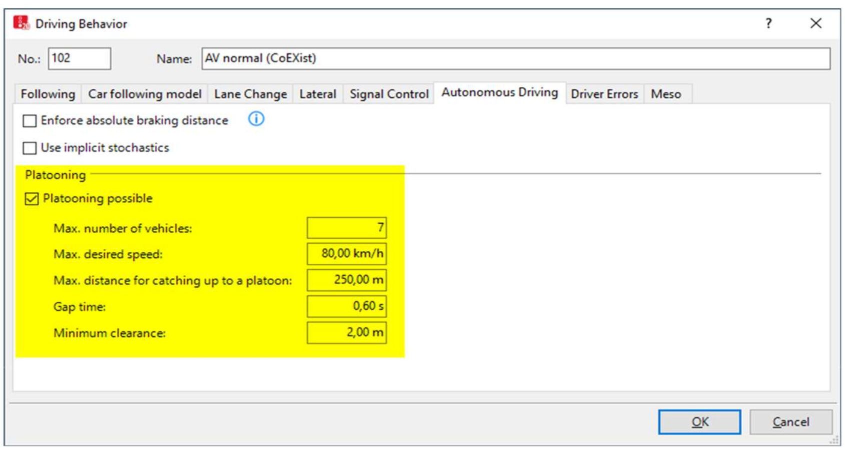

Figure 11 Platooning activation & parameters

3.11 Lane-specific driving behaviour

It allows the user to define individual “link behaviour type” for each traffic lane, which means that vehicles can use different driving behaviour on each lane. This allows the user to activate some special driving behaviour/parameters only for selected lane(s) (e.g. for automated vehicles, automated pods, unmanned delivery vehicles or conventional vehicles). Link behaviour types for each lane can be set through the link dialog (shown in Figure 12) or a link list with the coupled list and selecting “lanes”.

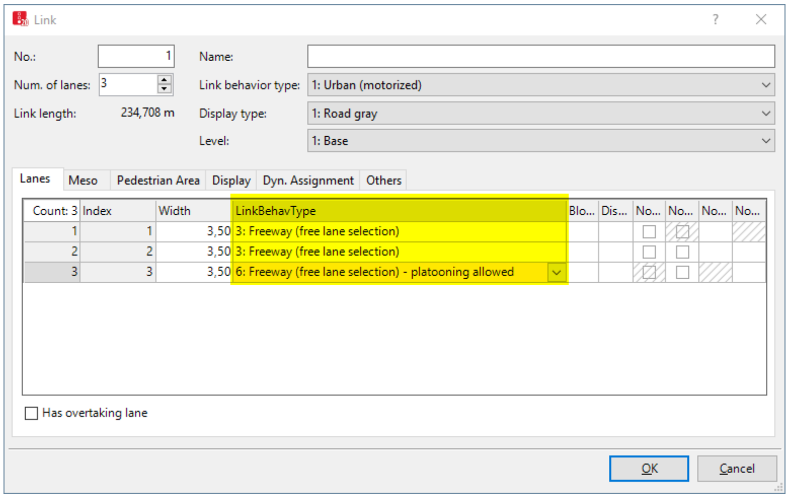

Figure 12 Link behaviour type for lanes in the link dialog

4 Appendixes

- Webinar I: PTV Vissim autonomous vehicles new features and how to
- Webinar II: CoEXist: Preparing the transition to automated vehicles
- Webinar III: New developments in PTV Vissim
- Webinar IV: CoEXist project & PTV Vissim

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PTV GROUP

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Welcome to the Webinar

PTV VISSIM: AUTONOMOUS VEHICLES NEW FEATURES AND HOW-TO

Presenter:

Peter Sukennik

PTV Vissim Product Management

PTV Group, Karlsruhe

peter.sukennik@ptvgroup.com

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OVERVIEW

1. Explicit vs. implicit stochastics
2. New features related to AV
3. Driving behavior parameters for AV
4. How to deal with cooperation & communication

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Presenter:

Peter Sukennik

PTV Vissim Product Management
PTV Group, Karlsruhe

Answering your questions:

Lukas Kautzsch

PTV Vissim Product Management
PTV Group, Karlsruhe

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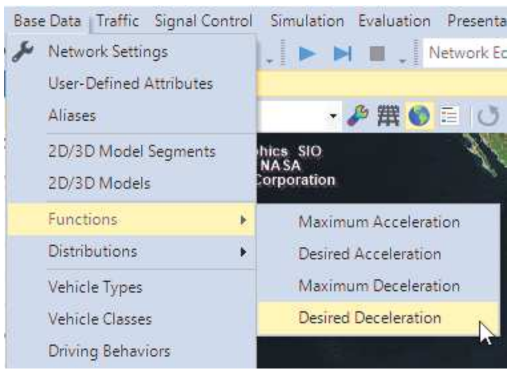
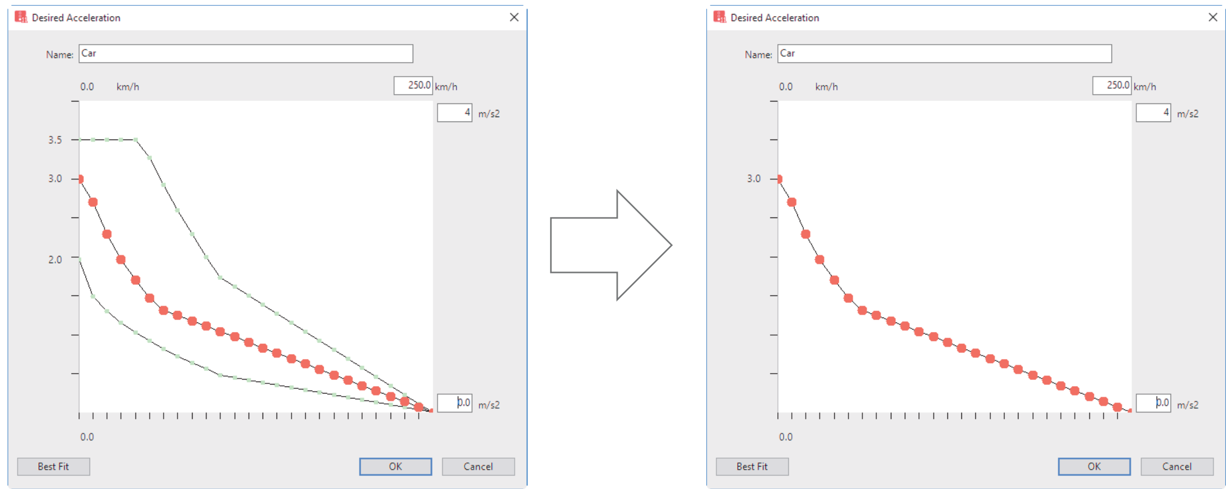
EXPLICIT STOCHASTICS

EXPLICIT STOCHASTICS - FUNCTIONS

Assumption: AVs accelerate/decelerate the same/very similar way

- Desired acceleration/deceleration
- Maximum acceleration/deceleration

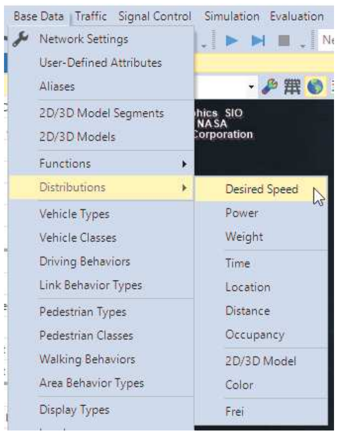


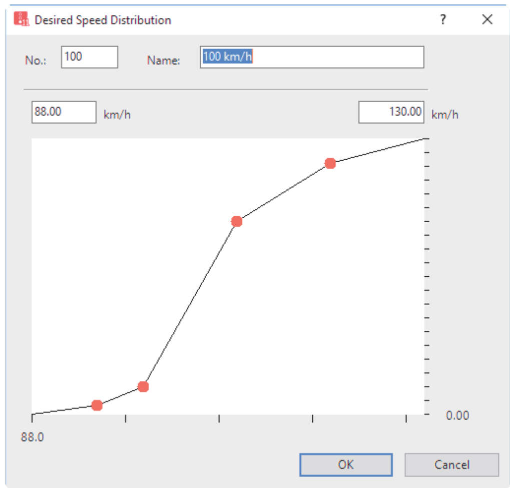


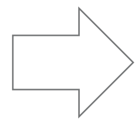
EXPLICIT STOCHASTICS - DISTRIBUTIONS

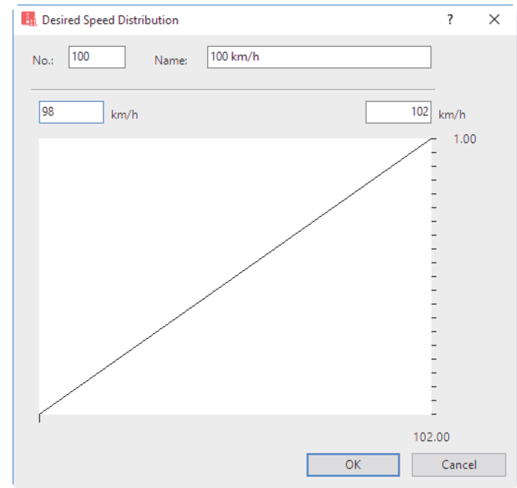
Assumption: AVs will respect the speed limit and the spread will be minimized

- Desired speed
- Time
- Distance
- Occupancy



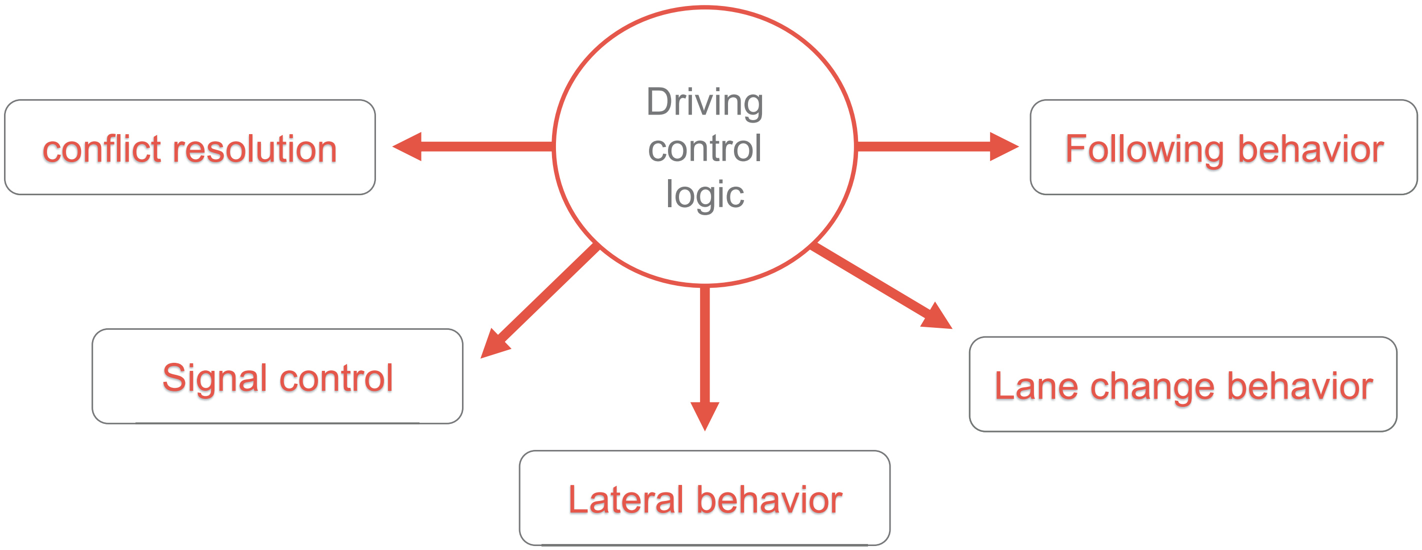






NEW FEATURES

AV DRIVING LOGIC



Definition under CoExist project:

Rail safe	Cautious	Normal	„all knowing“
• Brick wall stop distance • Big gaps • Predefined route • No lane change • No unprotected signal phase • Higher lateral distance or physical separation • Mostly closed environment	• Brick wall stop distance • Big gaps • Cautious behavior	• Gaps similar to human drivers but with higher safety	• Smaller gaps but still safe • Cooperative behavior • Communication is a precondition

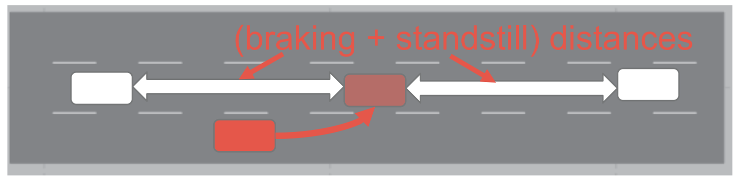
ENFORCE ABSOLUTE BRAKING DISTANCE

Idea: the vehicle can stop safely anytime (without a crash), even if the leading vehicle stops instantly ("turns into brick wall")

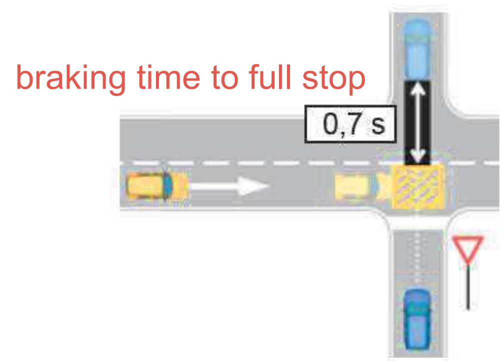
Implications for:

- Following behavior

- Lane change behavior



- Gap acceptance at intersections (conflict areas only)
  Rear gap = time to brake to full stop 1 m in front of the conflict area



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NUMBER OF INTERACTION VEHICLES

Vissim 10:

- Number of observed vehicles

The following network objects are modeled as vehicles in Vissim. Vehicles treat these network objects as a preceding vehicle:

- Red signal heads
- Reduced Speed Areas
- Priority rules (if the minimum time gap or minimum headway condition is not met)

Vehicles also treat the following network objects as a preceding vehicle if they have to stop there:

- Stop Signs
- Public transport stops
- Parking Lots

Conflict areas behavior: A vehicle takes into consideration all conflict areas up to the n-th preceding vehicle (for n observed ~~vehicles)~~ interaction objects (up to max. look-ahead distance if there is no object).

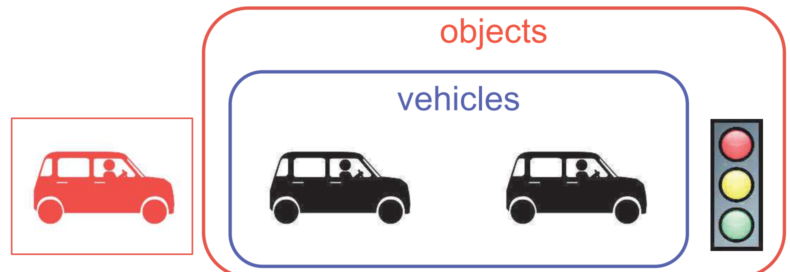
Vissim 11:

- Number of interaction objects
- Number of interaction vehicles

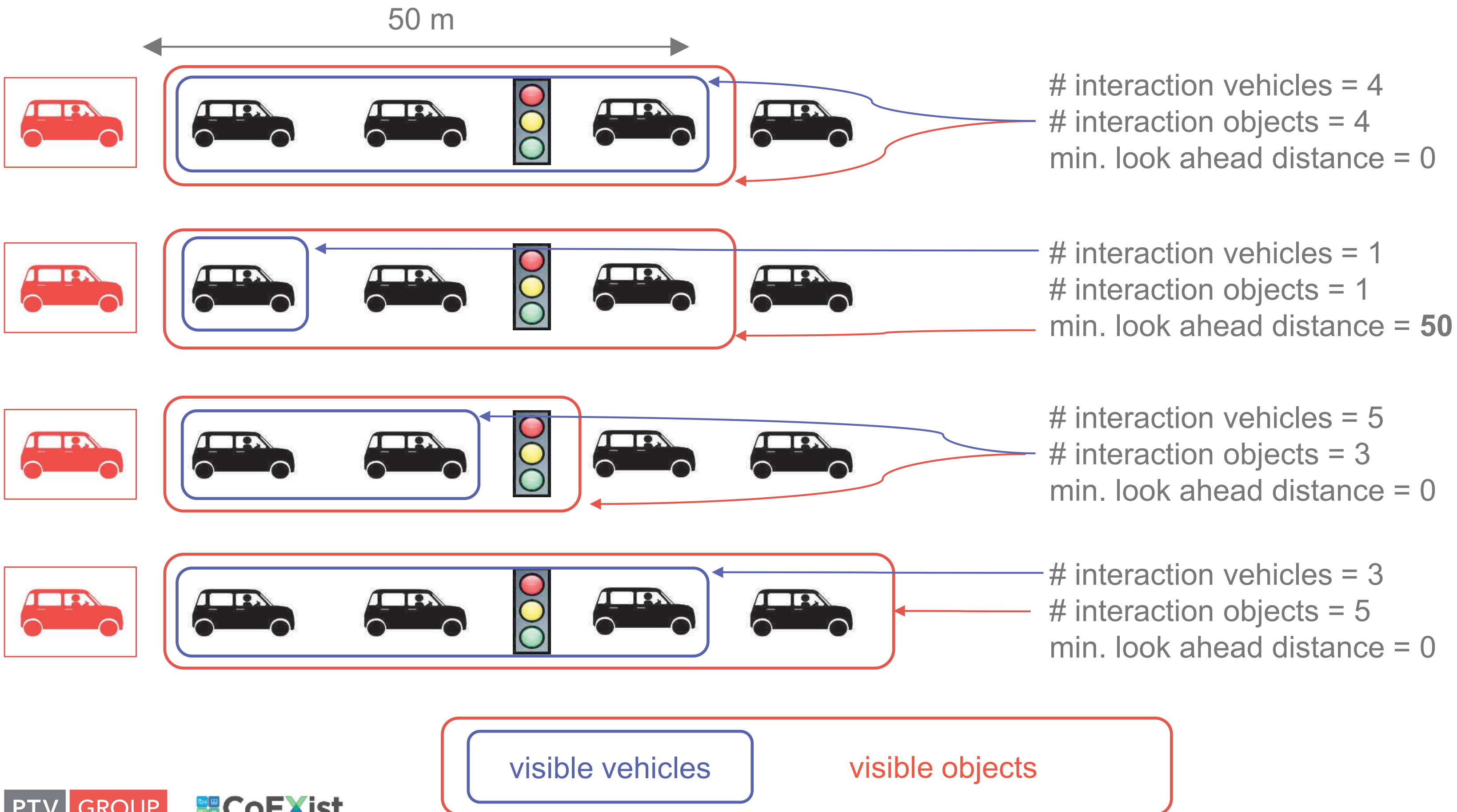
limits the number of visible vehs within the min. look-ahead dist.

Idea: automated vehicle can see the signals ahead, but only one (or two…) vehicle(s) in front of itself because the sensors cannot see through the leading vehicle

Settings	Behavior
#obj < #veh	As Vissim 10
#obj >= #veh	New limited sight and interaction behavior



NUMBER OF INTERACTION VEHICLES – CONFIGURATION EXAMPLES



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USE IMPLICIT STOCHASTICS

Idea: the stochastic imperfection of human driving is replaced by deterministic machines.

In the internal behavior model (for humans), there are several stochastic values indicating the spread of human behavior:

- the risk acceptance,
- the ability to estimate distance and speed difference,
- the precision when operating the throttle and braking pedals.

⇨ For AVs, deterministic values for these parameters can be assumed.

If the attribute "use implicit stochastics" is false, a deterministic average value is used instead of such a stochastically distributed value whenever the distribution cannot be set by the Vissim user.

This option affects:

- desired safety distance,
- desired acceleration,
- desired deceleration,
- decision points (when to start braking / accelerating).

the user may also specify a distribution or function but these are not adjusted automatically, only an implicit stochastic term is suppressed

INCREASED ACCELERATION

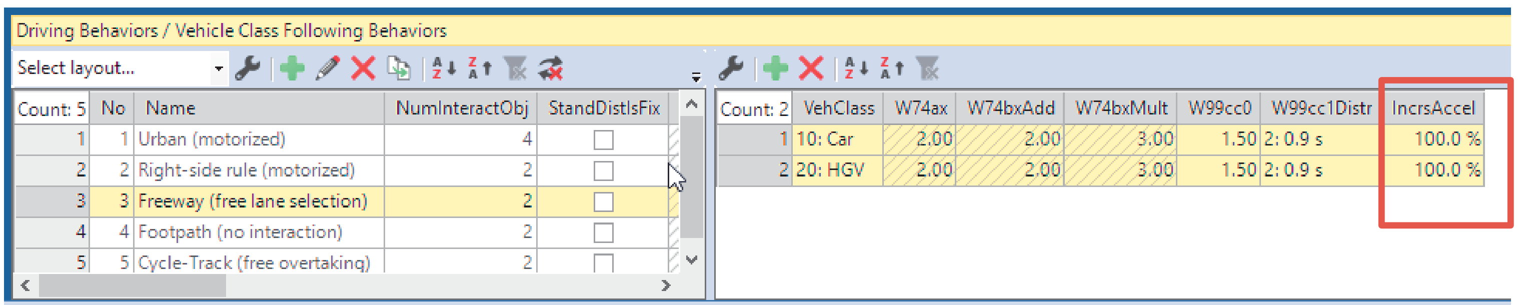
Idea: AVs, especially if using C2C communication, can use a tight coupling with small headways.

The normal “human” acceleration behavior cannot use reliable information about the future behavior of the leading vehicle.

⇨ normal Vissim vehicles tend to fall behind when the leading vehicle is accelerating.

In order to allow vehicles to keep a small headway even during an acceleration process, there is the **new parameter “Increased acceleration”**.

This value defines a percentage (usually > 100%) of the normal acceleration to be used when the leading vehicle is accelerating. The vehicle cannot exceed its maximum acceleration (which defines the technical limit) but it can exceed its desired acceleration in this situation.



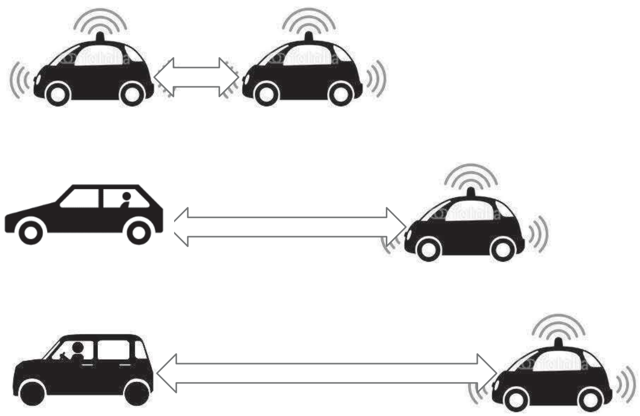
NEW FEATURES & DRIVING LOGICS

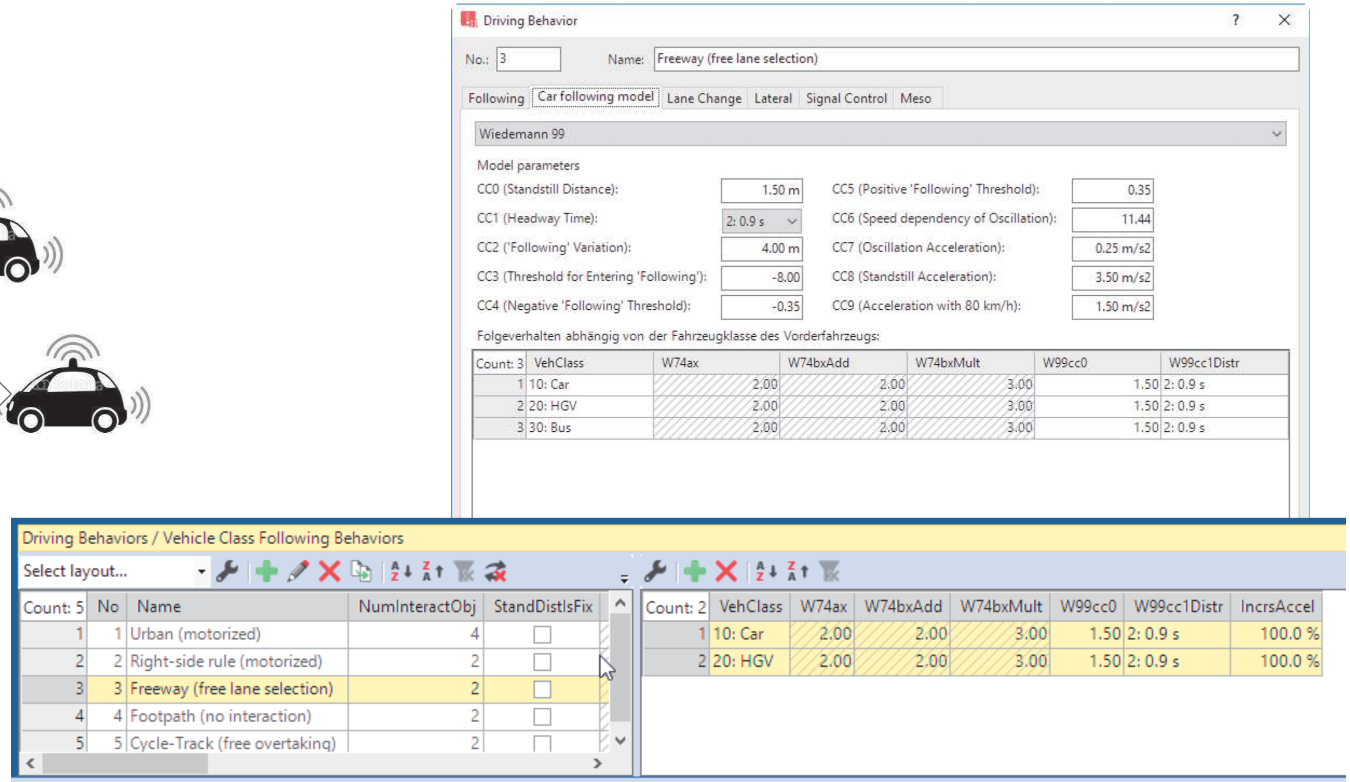
	recommended setting for new features			
driving logic	enforce absolute breaking distance (EABK)	use implicit stochastics	number of interaction vehicles*	increased desired acceleration
rail safe	ON	OFF	1	100%
cautious	ON	OFF	1	100%
normal	OFF	OFF	1	100-110%
all knowing	OFF	OFF	>1	110%

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

HEADWAY BASED ON LEADING VEHICLE CLASS

Idea: the headway to followed vehicle depends on the followed vehicle type



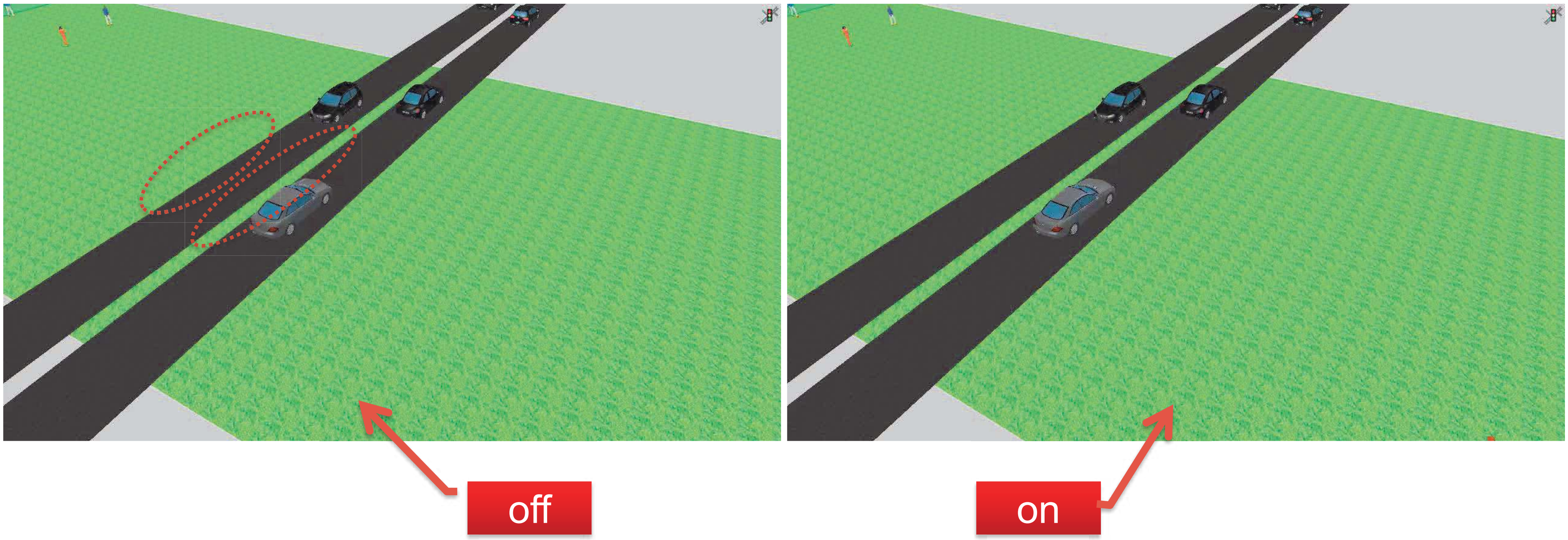


Implementation:

- New field in the dialog
- New coupled list for following analogical to „lateral“

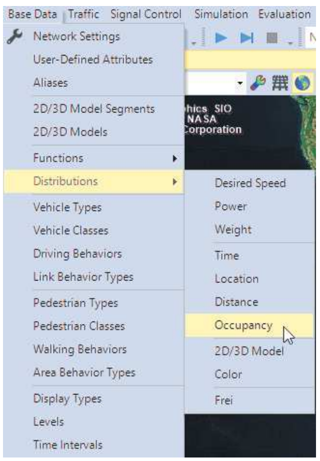
CONSIDER VEHICLES IN DYNAMIC POTENTIAL

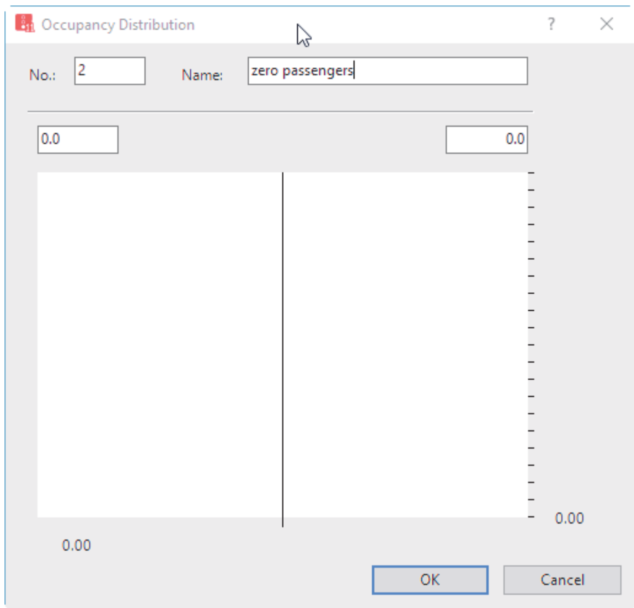
Idea: pedestrians find gaps between standing vehicles to cross the road

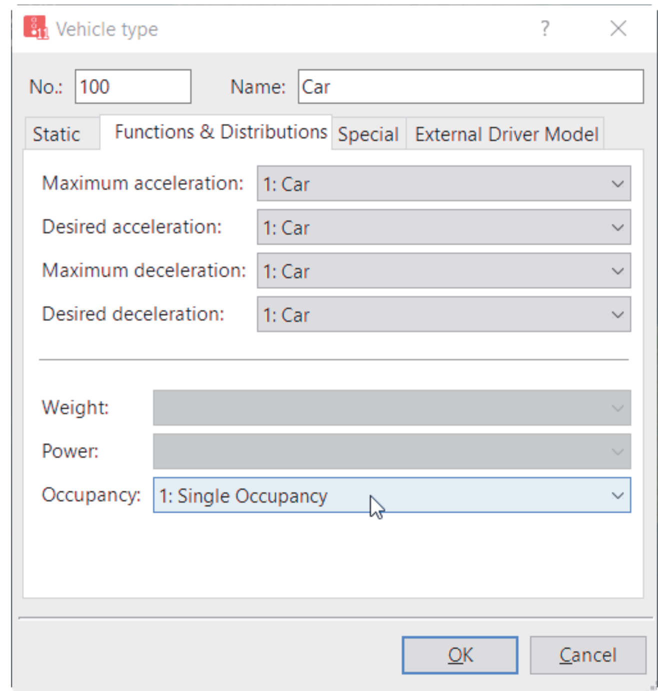


ZERO PASSENGERS

- Occupancy distribution (empirical) with value 0 possible now
- Simply to allow empty trips for future autonomous vehicles







OPENDRIVE IMPORT (INFO)

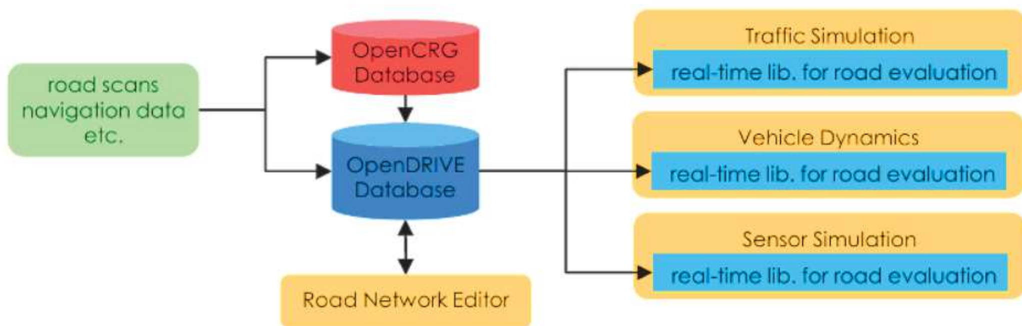
http://www.opendrive.org

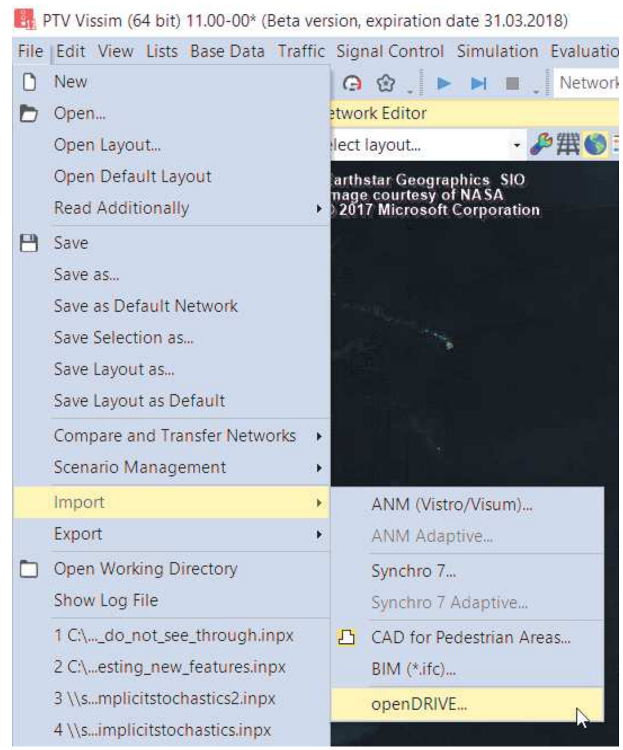
OpenDRIVE = open file format for the logical description of road networks. It has been developed and is being maintained by a team of simulation professionals with large support from the simulation industry. Its first public appearance was on January 31, 2006.

- Import restricted to links & connectors

Usage

The following figure shows the typical incorporation of an OpenDRIVE® file into a simulation tool-chain:





DRIVING BEHAVIOR PARAMETERS

DRIVING BEHAVIOR PARAMETERS: FOLLOWING

PTV Vissim uses the Wiedemann models.

Parameters control the driving behavior during the following process.

	model	parameter**	driving logic			
			rail safe	cautious	normal	all knowing
following behavior	Wiedemann 99	CC0	def	def	def	smaller
		CC1	def/higher*	def/higher*	def	smaller
		CC2	def/smaller	def/smaller	smaller	smaller
		CC3	def/higher	def/higher	def	def
		CC4	Smaller	def/smaller	def/smaller	smaller
		CC5	Smaller	def/smaller	def/smaller	smaller
		CC6	def/smaller	def/smaller	def	smaller
		CC7	def/smaller	def/smaller	def/smaller	smaller
		CC8	Smaller	smaller	def	def
		CC9	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 is on, brick wall stop distance is guaranteed ** see PTV Vissim manual for detailed description

	model	parameter**	driving logic				
			rail safe	cautious	normal	all knowing	def
following behavior	Wiedemann 99	CC0	1.5	1.5	1.5	1	1.5
		CC1	1.5	1.5	0.9	0.6	0.9
		CC2	0	0	0	0	4
		CC3	-10	-10	-8	-6	-8
		CC4	-0.1	-0.1	-0.1	-0.1	-0.35
		CC5	0.1	0.1	0.1	0.1	0.35
		CC6	0	0	0	0	11.44
		CC7	0.1	0.1	0.1	0.1	0.25
		CC8	2	3	3.5	4	3.5
		CC9	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

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DRIVING BEHAVIOR PARAMETERS: LANE CHANGE

Parameters controlling the necessary lane change behavior (because of the route):

	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

	control 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

DRIVING BEHAVIOR PARAMETERS: LANE CHANGE

Parameters controlling the necessary (because of the route) & free (overtaking) lane change behavior:

	control 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

	control 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

DRIVING BEHAVIOR PARAMETERS: SIGNAL CONTROL

Parameters control the reactions on signals.

	driving logic			
attribute	**rail safe***	**cautious****	**normal**	**all knowing**
behavior at amber signal	continuous check	continuous check	one decision***	one decision
behavior 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

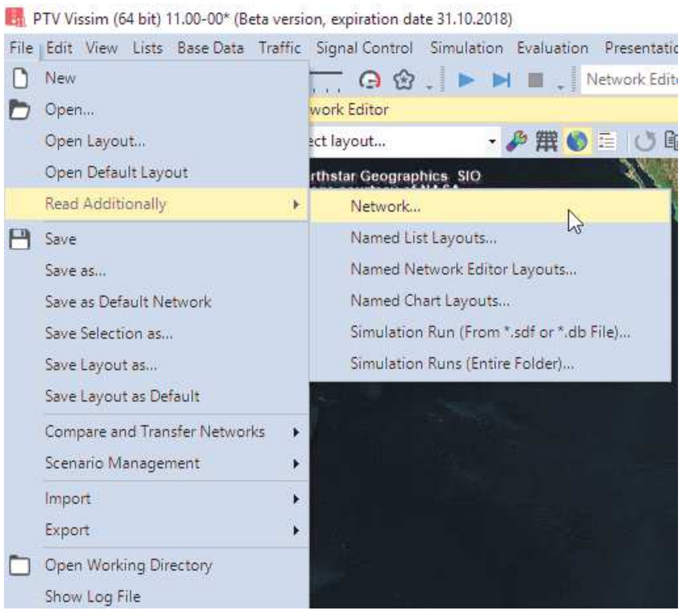
** probably protected phases only, EABD must be on

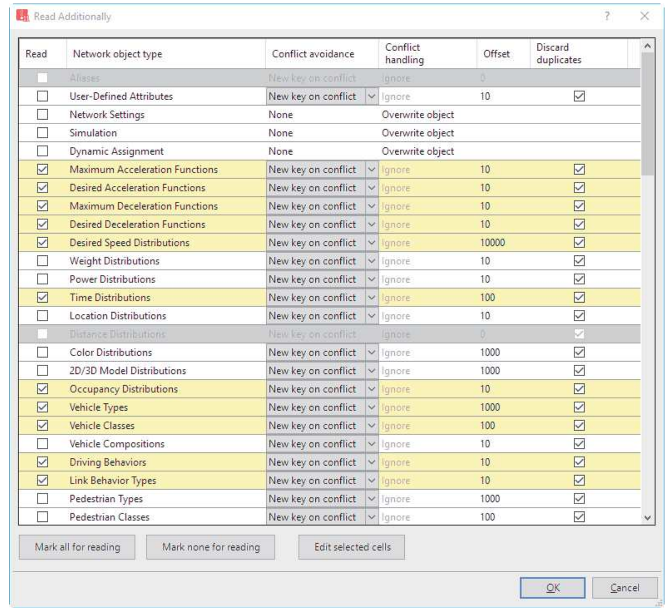
*** requires that the AV can remember that it has made a decision for that particular signal head already, else: continuous check

	driving logic				
attribute	**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

IMPORT OF PREDEFINED PARAMETERS INTO YOUR NETWORK

PTV Vissim file “base network” available – contains recommended values for cautious, normal & all knowing driving logic – of course these can be adjusted if needed.





COOPERATION & COMMUNICATION

Questions to answer:

- What is the impact of a communication/cooperation?
- Can I replicate expected behavior with standard PTV Vissim or do I need an interface?

Available interfaces:

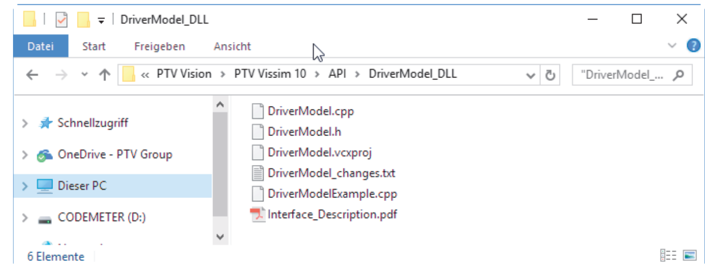
- **COM** => allows to read & set attributes of Vissim objects or to manipulate them
  - Usable for V2V or V2I communication, e.g. for platooning or time slot based intersection control
  - Examples available in …\Documents\PTV Vision\PTV Vissim 10\Examples Training\Autonomous Vehicles (AV)
- **DriverModel.dll** => replace internal car following behavior model of Vissim by own algorithm + optionally:
  - Own algorithm for lane changing
  - Own algorithm for reaction on signals
- **DrivingSimulator.dll** => couple own control algorithm (full behavior) with Vissim + optionally integration of:
  - Vehicle dynamics
  - Sensors

  ⇨ nanosimulation

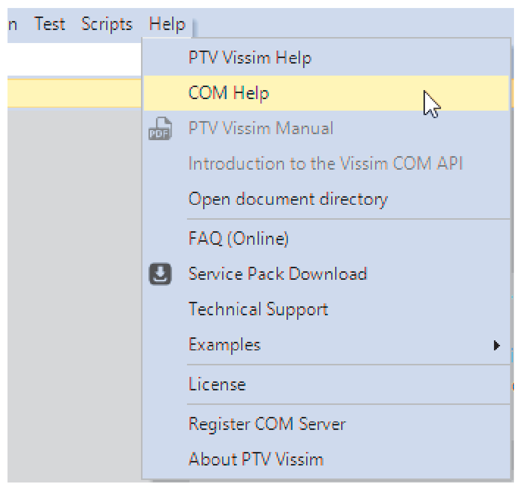
  Third party software (PreScan, CarMaker…) can be coupled with Vissim => co-simulations.

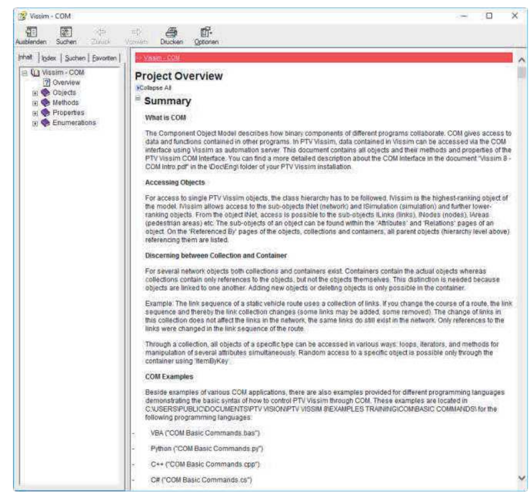
MATERIALS FOR INTERFACES

- Interface descriptions & example files – see the installation directory
  - C:\Program Files\PTV Vision\PTV Vissim 10\API\DriverModel_DLL
  - C:\Program Files\PTV Vision\PTV Vissim 10\API\DrivingSimulator_DLL



- COM Help & Examples – see the examples directory
  - …\Documents\PTV Vision\PTV Vissim 10\Examples Training\COM
  - Recommended: "…COM\Basic Commands" for instruction & tips in different programming languages
  - …\Documents\PTV Vision\PTV Vissim 10\Examples Training\Autonomous Vehicles (AV)





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Preparing the transition to Automated Vehicles

Alastair Evanson, PTV Vissim Solution Director

11/04/2019

Agenda

1. Introduction to the Project
2. Study Locations
3. Core Tasks
4. Outcomes

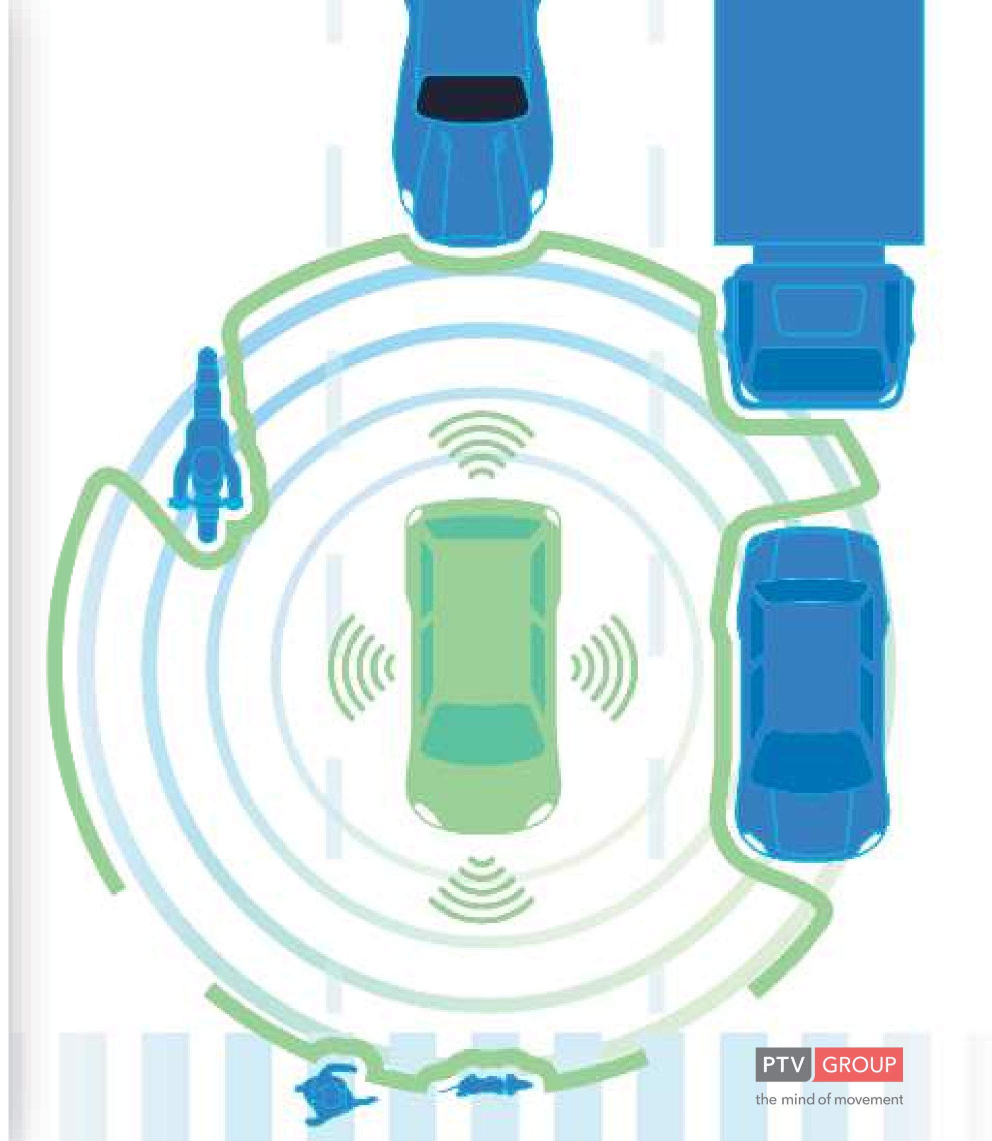
What is CoEXist?

A European Union funded Horizon 2020 Project.

CoEXist develops an AV-ready framework for road authorities and fosters technological development of traffic simulations tools.

By simulating automated vehicles in four European cities, with different urban structures and traffic compositions, CoEXist analyses the effects of automated vehicles on urban road infrastructure, especially in a context of "co-existence" between automated and conventional vehicles.

The results of the project will enable road authorities to understand in detail the impact of increasing numbers of automated vehicles and to plan accordingly.



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CoEXist Mission

The mission of CoEXist is to systematically increase the capacity of road authorities and other urban mobility stakeholders to get ready for the transition towards a shared road network with an increasing number of automated vehicles.

By simulating automated vehicles in four European cities, with different urban structures and traffic compositions, CoEXist analyses the effects of automated vehicles on urban road infrastructure, especially in a context of "co-existence" between automated and conventional vehicles.

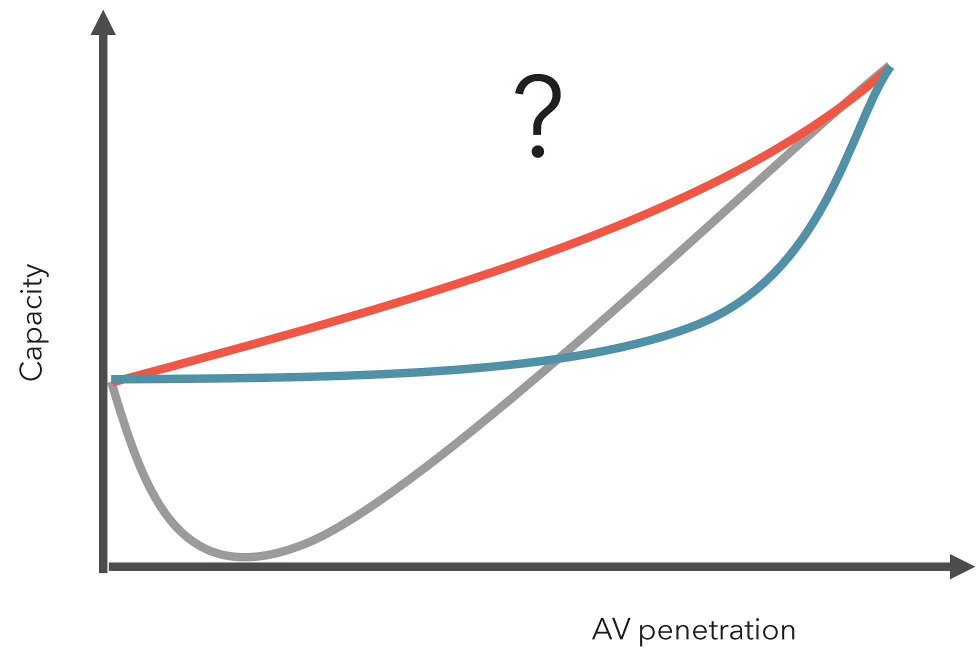
CoEXist aims at enabling mobility stakeholders to get "AV-ready" (Automated Vehicles-ready).

To achieve its objective, CoEXist develops a specific framework and both microscopic and macroscopic traffic models that take the introduction of automated vehicles into account.

Co-existence of AV & Conventional vehicles

Unclear transition to full (?) autonomy.

- Results strongly depend on assumptions made.
- Models needed to evaluate assumptions.



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CoEXist Study Locations

Microscopic

Macroscopic

CoEXist Study Locations

Impact of AVs on highway / transition zones

- Penetration Rates

Signalized urban traffic junctions

- Mixed Traffic
- V2I & V2V

Microscopic

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CoEXist Study Locations

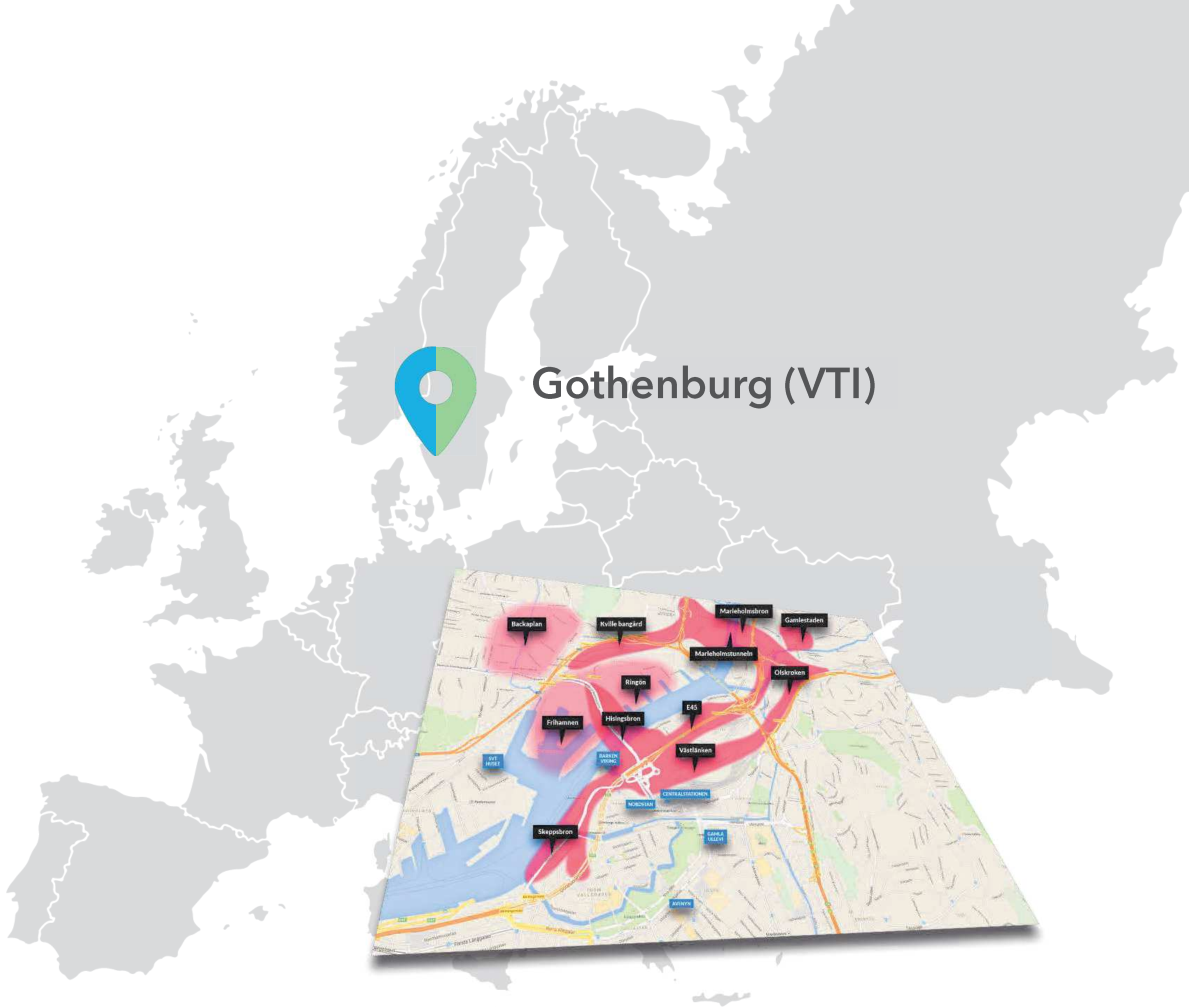
Shared Space

- Co-existence of different modes in informal infrastructure environment.

Long term constructions

- Resilience of infrastructure to accommodate mixed fleet.
- Help to plan large capital schemes with future mixed fleets.

Microscopic **Macroscopic**



CoEXist Study Locations

Parking:

- Drop off/ pick up and self parking operations.
- Vehicle return and infrastructure layouts.

Freight:

- Urban logistics.
- Autonomous delivery pods.

Microscopic

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CoEXist Study Locations

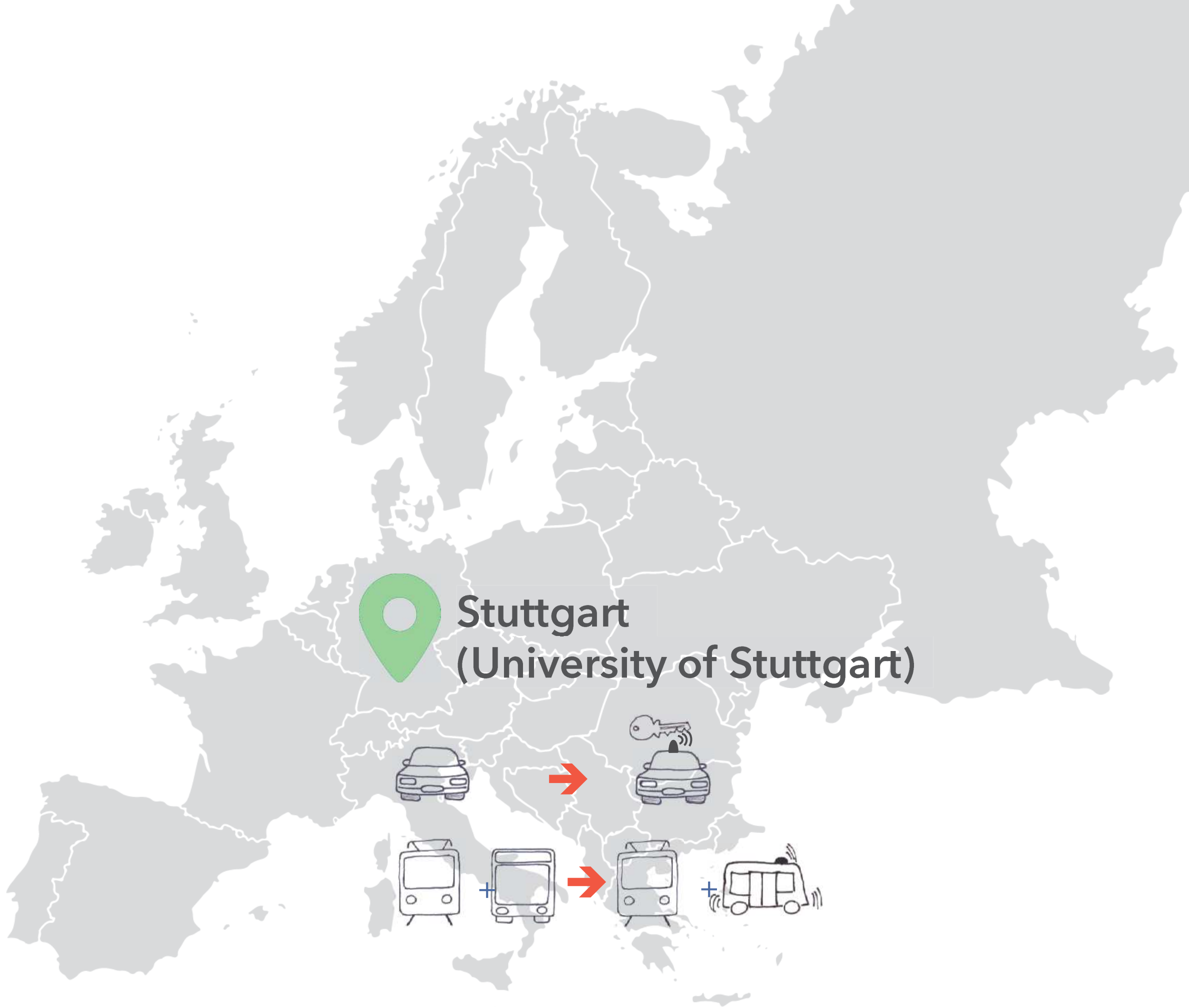
Network categorisation:

- Capacity of network with mixed fleets.
- Designation of roads/ routes to certain vehicle types.

Ridesharing systems:

- Car sharing & public ridesharing.
- Multi-chain, multi-modal trips.

Macroscopic



Core Tasks

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Core Tasks: AV ready traffic modelling tools

Validated extension of existing microscopic transport models to include different types of automated vehicles.

Assessing the impact of automated vehicles on:

- Safety
- Traffic efficiency
- Space demand and development of design guidance for hybrid infrastructure

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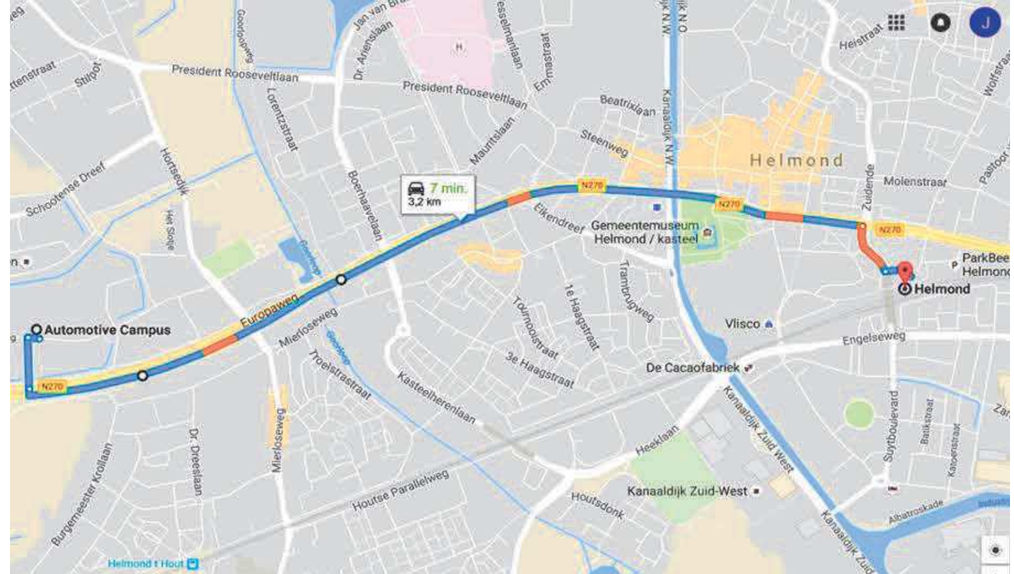
Core Tasks: AV ready traffic modelling tools

Define requirement for CAV-ready traffic flow simulation

- To establish a real-time and realistic connection between the AV-control logics, the AV-simulator and the microscopic modelling tool.
- To develop a set of model-based default values for AVs, including passenger car and light-freight vehicles.
- To collect data of two AVs on the public test site for validation of microscopic modelling tool.
- To extend micro- and macroscopic modelling tools to enable analysis of AV/CV-coexistence on the same network.



Core Tasks: AV ready traffic modelling tools

Micro

PTV VISSIM

Macro

PTV VISUM

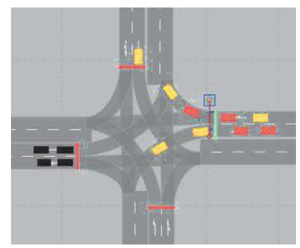
Interface approach:

- Improve APIs
- For users who have their own control algorithms (OEMs & Researchers)

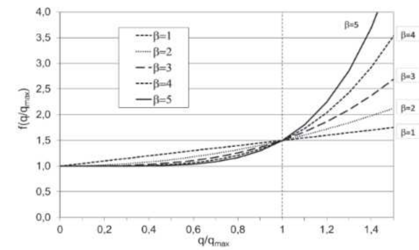
PTV VISSIM

Internal approach:

- Improve AV behavior
- For traditional Transportation Engineers (Planners, Consultants, Traffic Engineers)



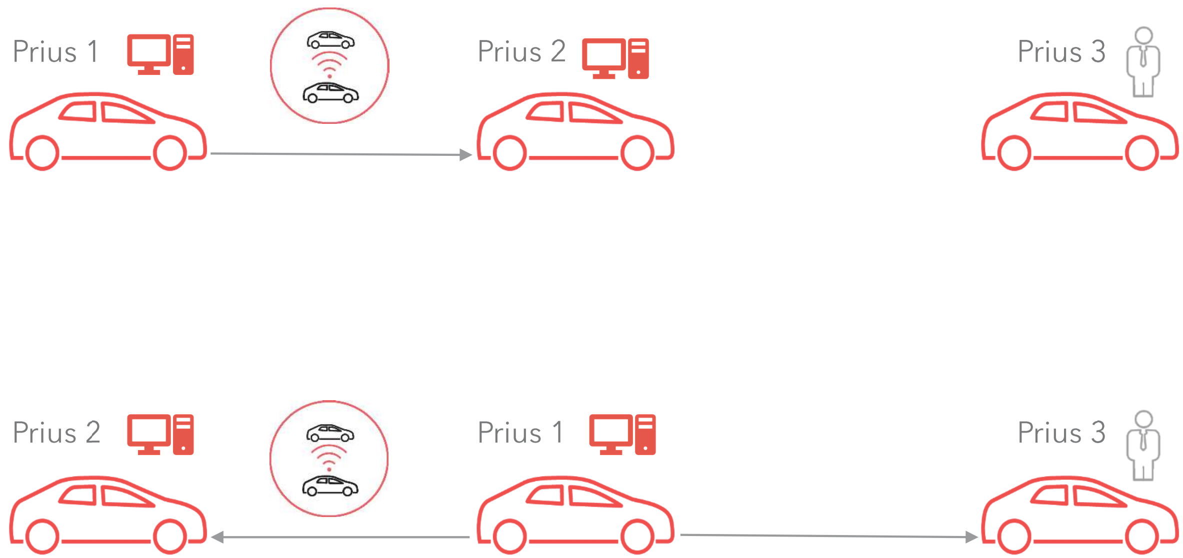
- Capacity
- Volume – Delay Function



Core Tasks: AV ready traffic modelling tools

Variations between the scenarios result in variations in the car following behaviour:

- Prius 1 and Prius 2 switch positions.
- Prius 1 and 2 communicate or don’t communicate.
- Predefined timegaps differ.



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Outcomes

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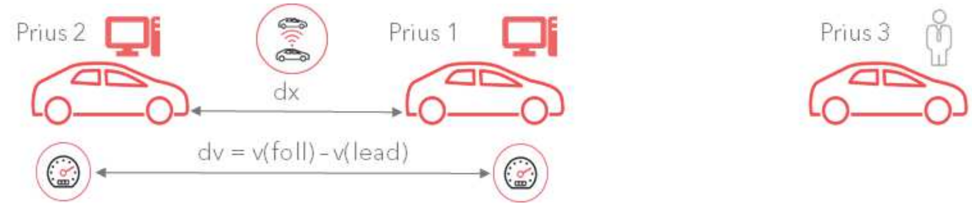
Test track data output

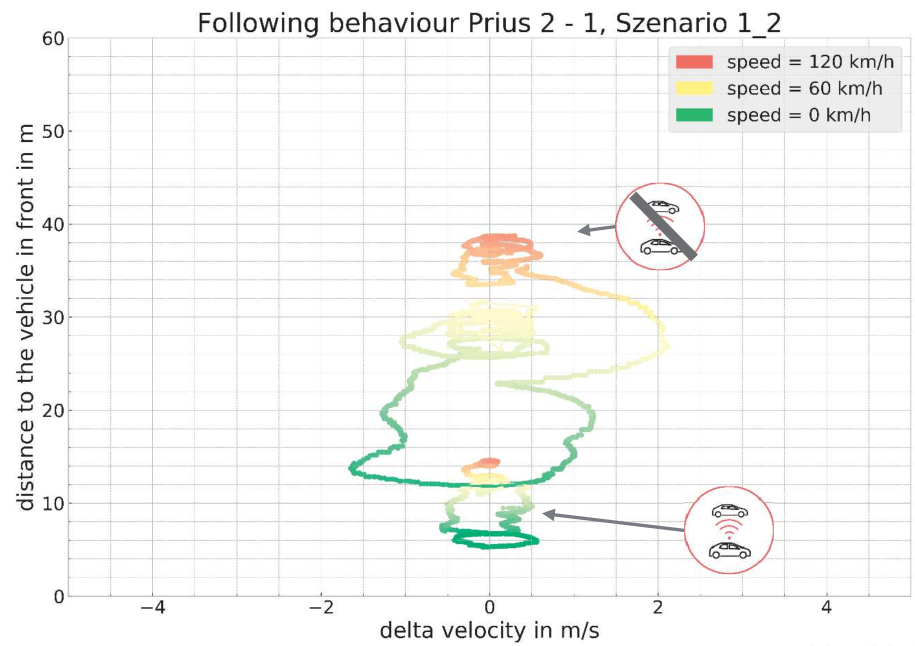
Vehicle trajectory and behaviour data recorded from the public test track and analysed to determine following behaviour.

Comparison of vehicle following behaviour for 'connected' and 'non-connected' scenarios. Distance to vehicle in front recorded for a variety of vehicle travelling speeds.

Key results of public road test:

- Safety distance in 'non-connected' scenario significantly higher than in 'connected' scenario.
- Reduced velocity in safety distance in 'connected' scenario compared to 'non-connected' scenario.





data points: 11798

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Validation of microscopic traffic modelling tools

Vehicle trajectory and behaviour data compared and validated against microscopic simulation (PTV Vissim) driving behaviours.

Existing microscopic simulator driving behaviours have much more oscillation than automated vehicles from road test.

Automated vehicle behaviour in microscopic simulation:

- Clear linear, deterministic relationship between following distance and speed.
- New automated vehicle behaviour parameters added to microscopic simulation (PTV Vissim) to achieve validation against real world public test automated vehicle data.

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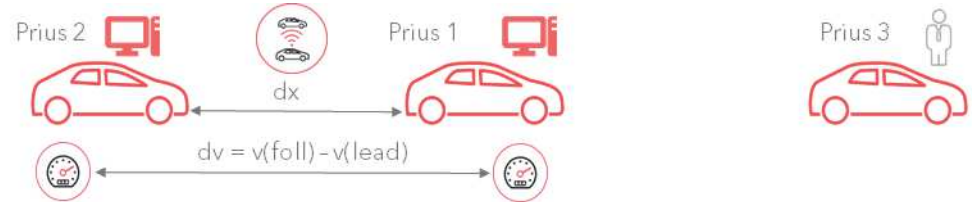
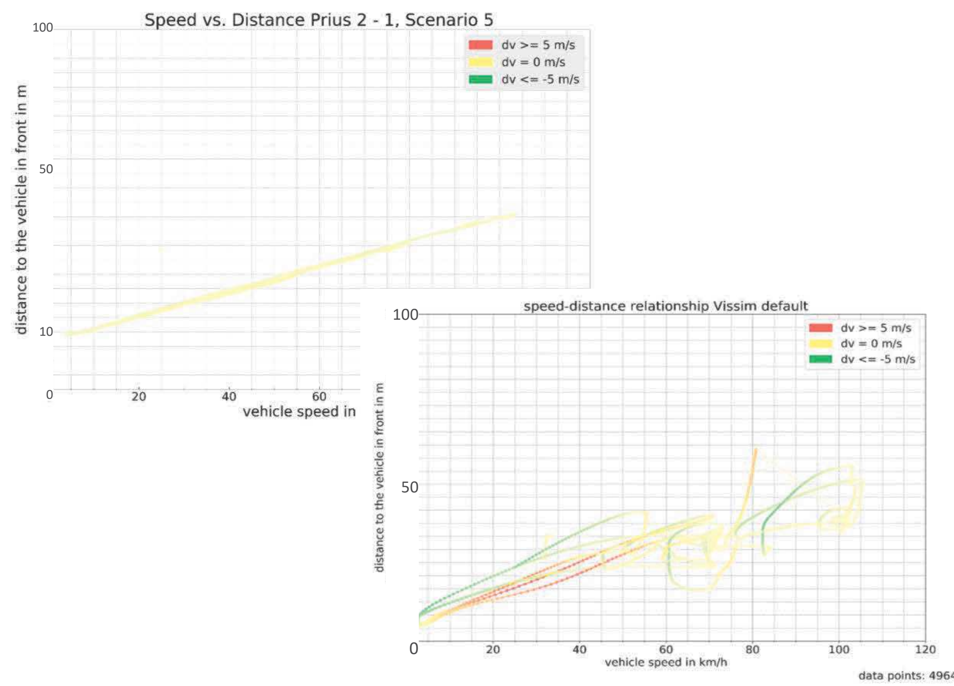


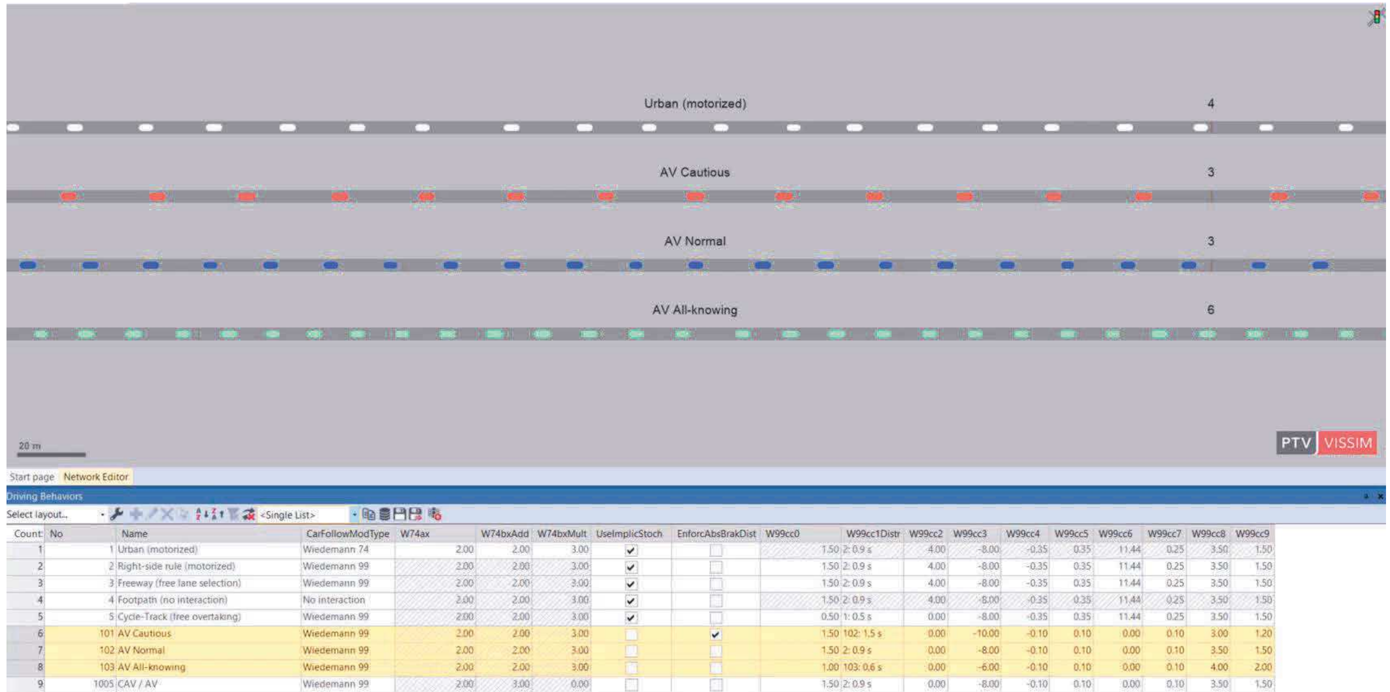


Automated vehicles simulation

Addition of new driving behaviours to PTV Vissim to replicated connected & automated vehicles.

AV Cautious / **AV Normal** / **AV All-knowing**

- Respects all road users / Exhibits average driver behaviour / Predicts other road users behaviours based on ability
- Replicates ability of sensors to communicate with other vehicles.
- Brick wall stop distance always maintained / to measure the distance and speed of other vehicles

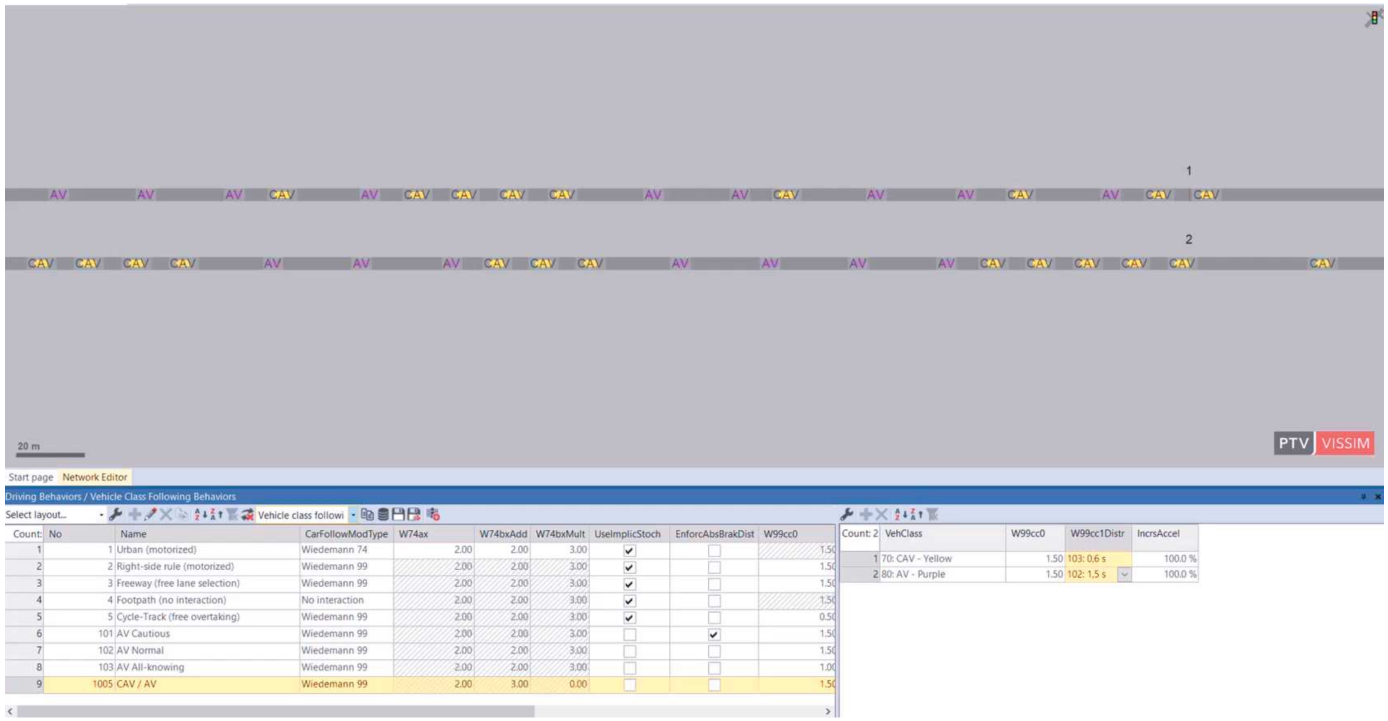


Count	No	Name	CarFollowModType	W74ax	W74bxAdd	W74bxMult	UseImplicStoch	EnforcAbsBrakDist	W99cc0	W99cc1Distr	W99cc2	W99cc3	W99cc4	W99cc5	W99cc6	W99cc7	W99cc8	W99cc9
1	1	Urban (motorized)	Wiedemann 74	2.00	2.00	3.00	✓		1.50	2: 0.9 s	4.00	-8.00	-0.35	0.35	11.44	0.25	3.50	1.50
2	2	Right-side rule (motorized)	Wiedemann 99	2.00	2.00	3.00	✓		1.50	2: 0.9 s	4.00	-8.00	-0.35	0.35	11.44	0.25	3.50	1.50
3	3	Freeway (free lane selection)	Wiedemann 99	2.00	2.00	3.00	✓		1.50	2: 0.9 s	4.00	-8.00	-0.35	0.35	11.44	0.25	3.50	1.50
4	4	Footpath (no interaction)	No interaction	2.00	2.00	3.00	✓		1.50	2: 0.9 s	4.00	-8.00	-0.35	0.35	11.44	0.25	3.50	1.50
5	5	Cycle-Track (free overtaking)	Wiedemann 99	2.00	2.00	3.00	✓		0.50	1: 0.5 s	0.00	-8.00	-0.35	0.35	11.44	0.25	3.50	1.50
6	101	AV Cautious	Wiedemann 99	2.00	2.00	3.00		✓	1.50	102: 1.5 s	0.00	-10.00	-0.10	0.10	0.00	0.10	3.00	1.20
7	102	AV Normal	Wiedemann 99	2.00	2.00	3.00			1.50	2: 0.9 s	0.00	-8.00	-0.10	0.10	0.00	0.10	3.50	1.50
8	103	AV All-knowing	Wiedemann 99	2.00	2.00	3.00			1.00	103: 0.6 s	0.00	-6.00	-0.10	0.10	0.00	0.10	4.00	2.00
9	1005	CAV / AV	Wiedemann 99	2.00	3.00	0.00			1.50	2: 0.9 s	0.00	-8.00	-0.10	0.10	0.00	0.10	3.50	1.50

Automated vehicles simulation

Addition of new driving behaviours to PTV Vissim to replicated connected & automated vehicles.

- Following behaviour can be altered depending on whether leading vehicle is human, AV or CAV.
- All automated vehicles adopt the same driving characteristics as the rest of the fleet, i.e. no variation between vehicles.



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PTV Vissim 11: AV Behaviors

Enforce Absolute Braking Distance

- Safe distance anytime

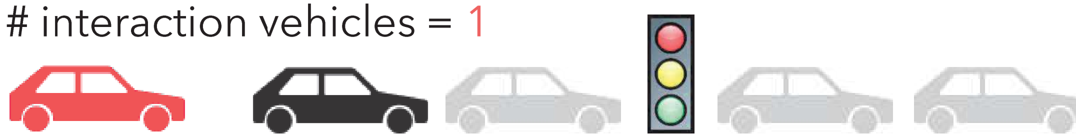
following distance =
braking distance + standstill distance

Interaction…

- vehicles
- objects

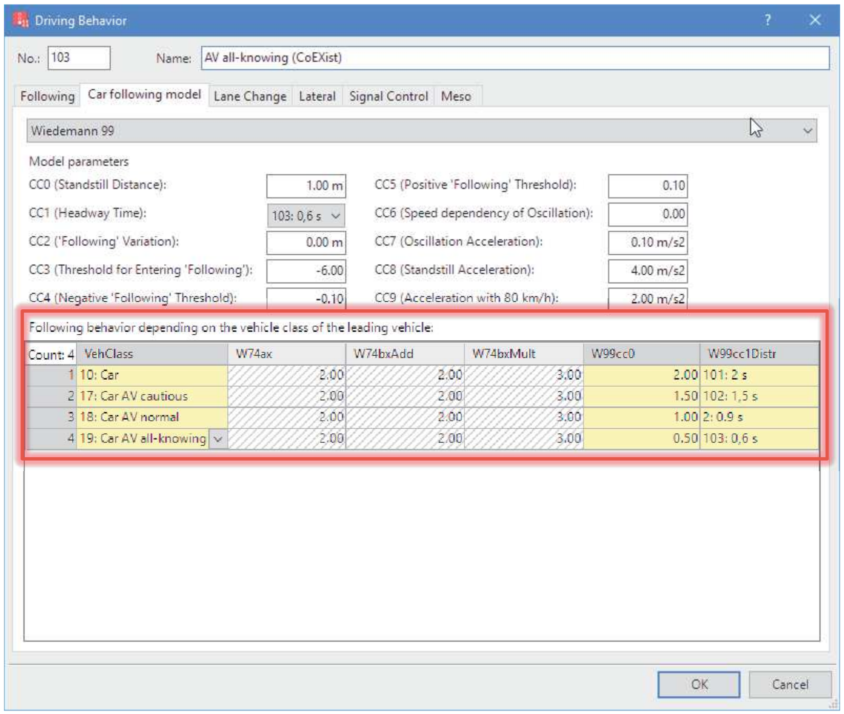
interaction objects = 4
interaction vehicles = 4

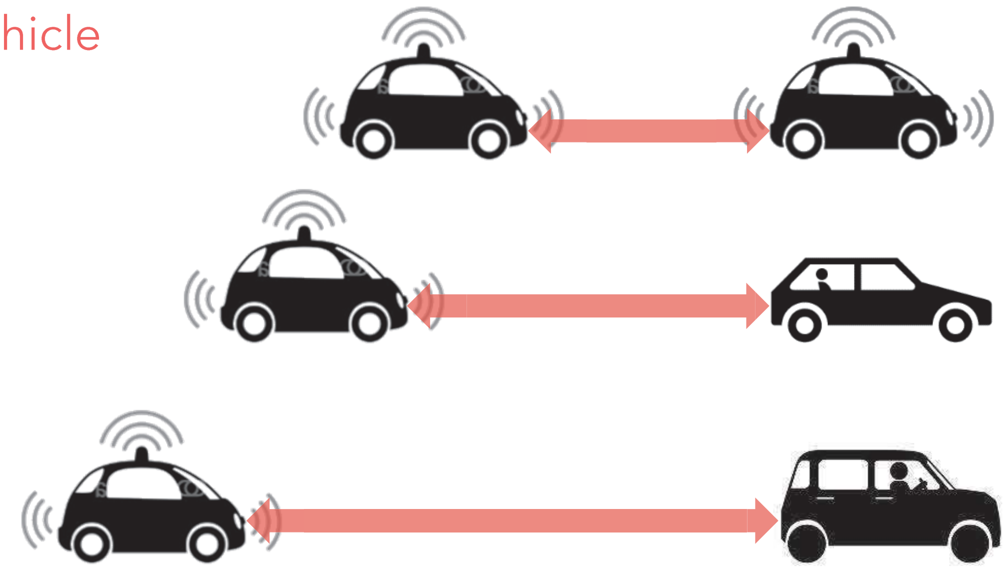
interaction objects = 4
interaction vehicles = 1



PTV Vissim 11: AV Behaviors

Headway Based on Class of Leading Vehicle





New Options

Use Implicit Stochastics

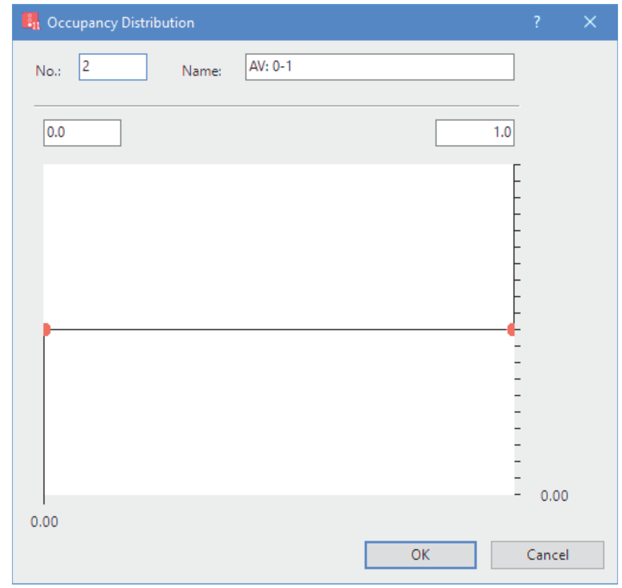
- No stochastic variation of internal parameters
- Used wherever distribution cannot be user-defined

Increased Acceleration

- Allow for constant distance even when accelerating
- Percentage (typ. > 100%)

Occupancy

- Empirical distribution can be 0



Next Steps

Application of microscopic simulation tools.

Taking the automated vehicle driving behaviour models and applying them in the use cases of the four partner cities of CoEXist.

- Simulate impact of co-existence of automated vehicles in mixed fleets.
- Assess required infrastructure to inform transition & facilitation of automation.

Innovation with PTV Vissim

- First application of automated vehicle behaviour embedded in commercially available software.
- Based on real world data from public test track with autonomous vehicle control algorithms.

CIVITAS SATELLITE

CoEXist

New developments in PTV Vissim

Peter Sukennik, PTV Group

#H2020CoEXist
@H2020_CoEXist

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 723201

Recap:

Features for driving behaviour

(since Vissim 11)

- Enforce absolute braking distance
- Use implicit stochastics
- Number of interaction vehicles
- Increased acceleration
- Gap time based on leading vehicle class
- Consider vehicles in dynamic potential
- Zero passengers
- Open drive import

See previous webinar
https://www.youtube.com/watch?v=C_bouqPNSw4

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Recap:

Driving behaviors

(since Vissim 11)

Modified parameters based on:

- CoEXist driving behavior concept
- Empirical data
- Co-simulation data
- Assumptions

Driving Behaviors

Select layout... <Single List>

Count: 8	No	Name	NumInteractObj	StandDistIsFix	StandDis
1	1	Urban (motorized)	4	☐	0.
2	2	Right-side rule (motorized)	2	☐	0.
3	3	Freeway (free lane selection)	2	☐	0.
4	4	Footpath (no interaction)	2	☐	0.
5	5	Cycle-Track (free overtaking)	2	☐	0.
6	101	AV cautious (CoEXist)	2	☐	0.
7	102	AV normal (CoEXist)	2	☐	0.
8	103	AV aggressive (CoEXist)	10	☐	0.

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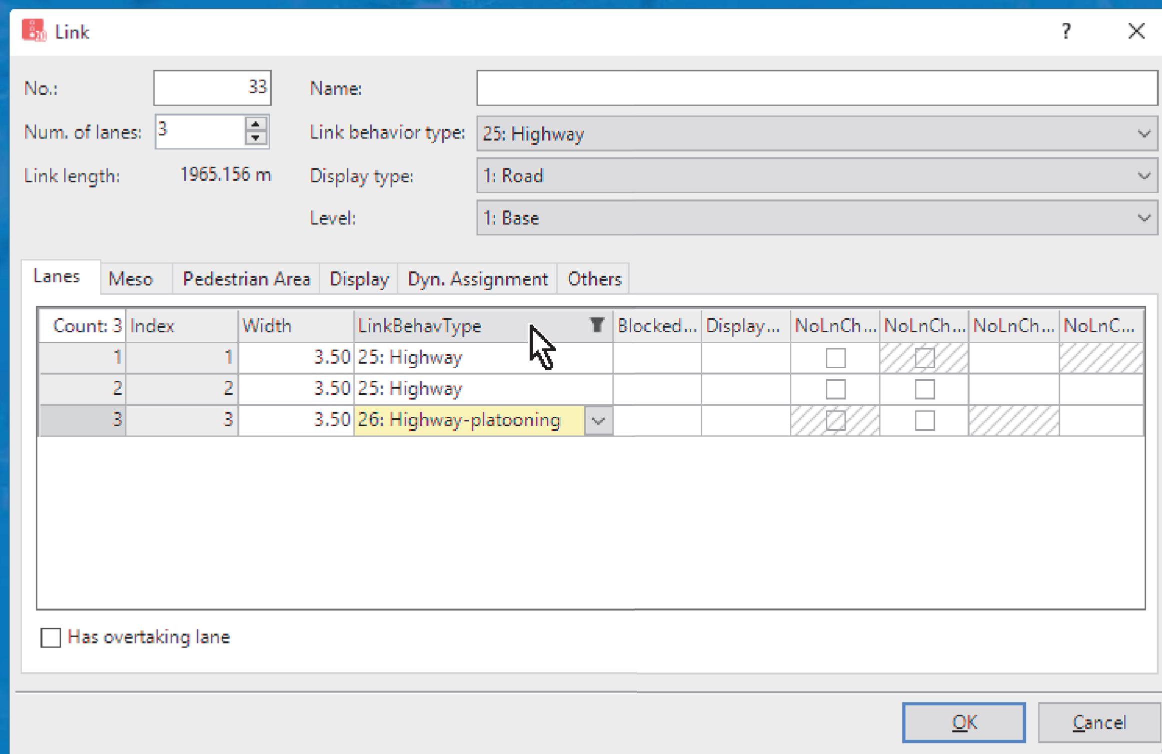
Lane specific driving behavior

(since Vissim 2020)

- Now, a link behavior type can be assigned to a lane.
- It overwrites the link behavior type.



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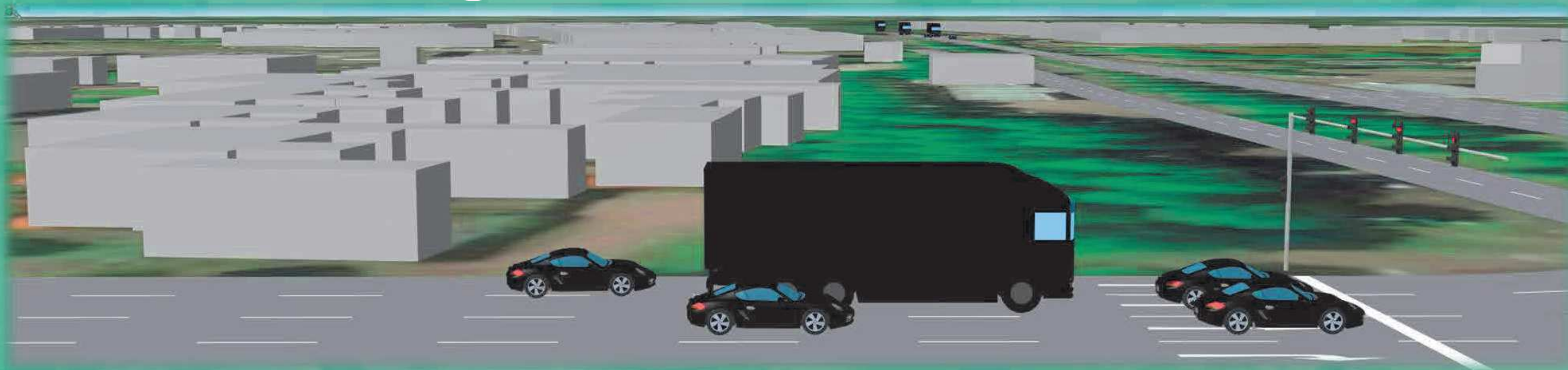
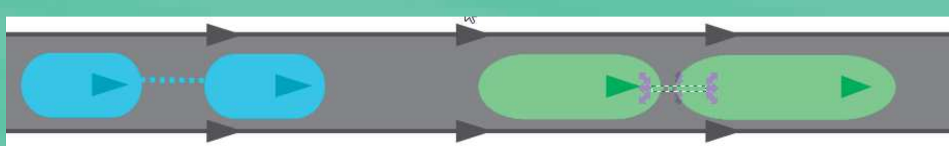
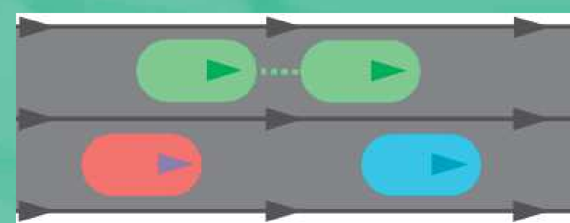
Platooning



- **Platoon** = **connected** vehicles traveling **very closely** & **safely** together, also at ***high speeds***
  - Use case: Simulate effects on general traffic
  - No simulation of platoon internals → stable driving
  - New driving behavior attributes



Vehicle class-specific



Lane-specific (new)

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Platoon Life Essentials

Joining

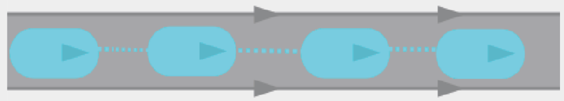
- Only vehicles with same driving behavior
- No PT or parking routes

Platooning

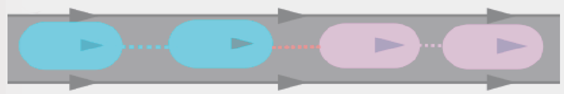
☑ Platooning possible

Max. number of vehicles:	8
Max. desired speed:	130.00 km/h
Max. distance for catching up to a platoon:	250.00 m
Gap time:	0.20 s
Minimum clearance:	1.50 m

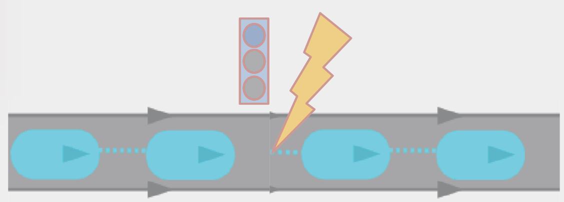
Driving



- No lane changes
- Keep same distance (speed-dependent)
- Limited acceleration change

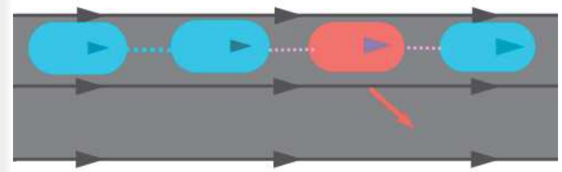


- Change of parameters



- Split platoon at red signals

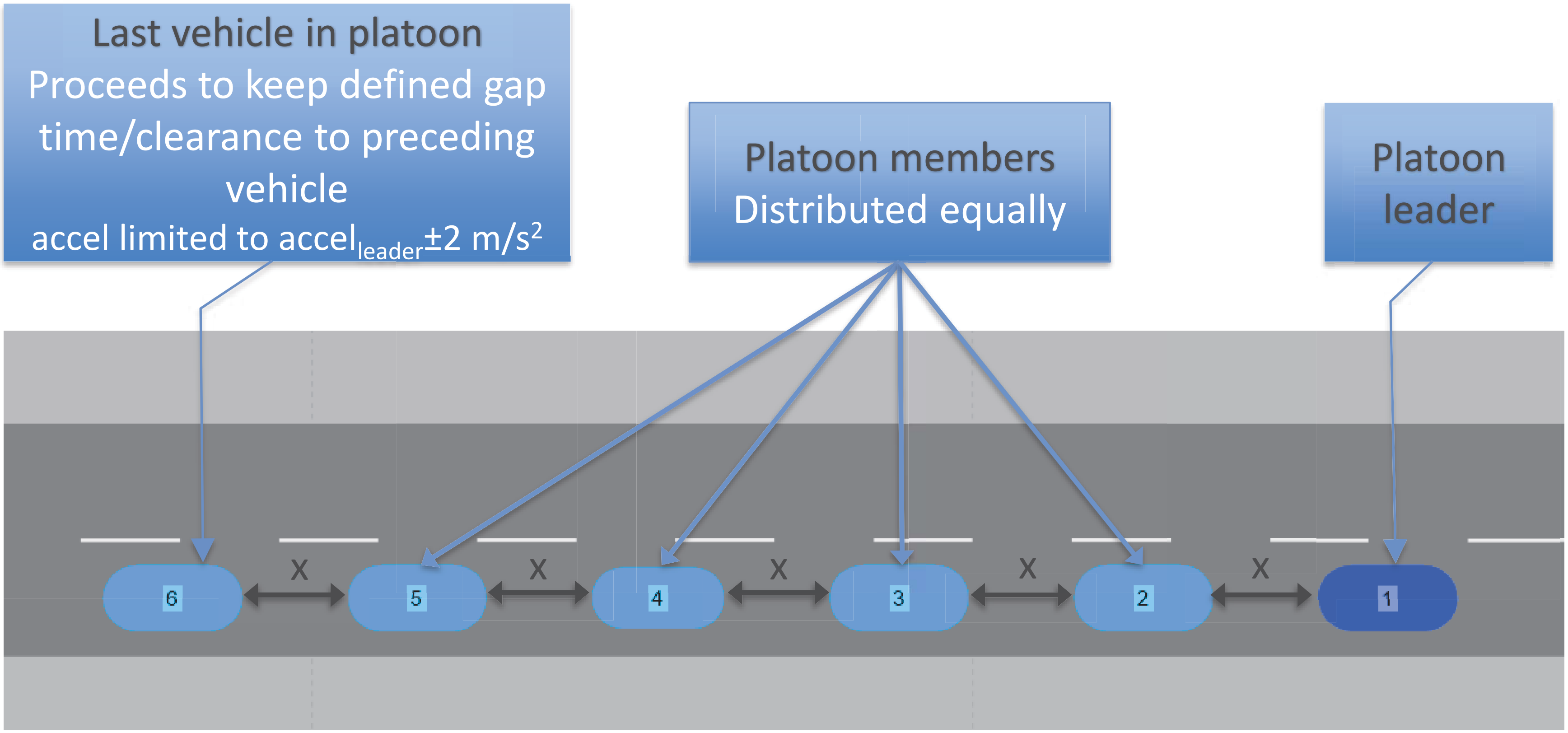
Leaving



- Increase distance (before and behind)
- Split platoon

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 723201

Platoon stability



No simulation of communication process itself: no packet sending or dealing with latency

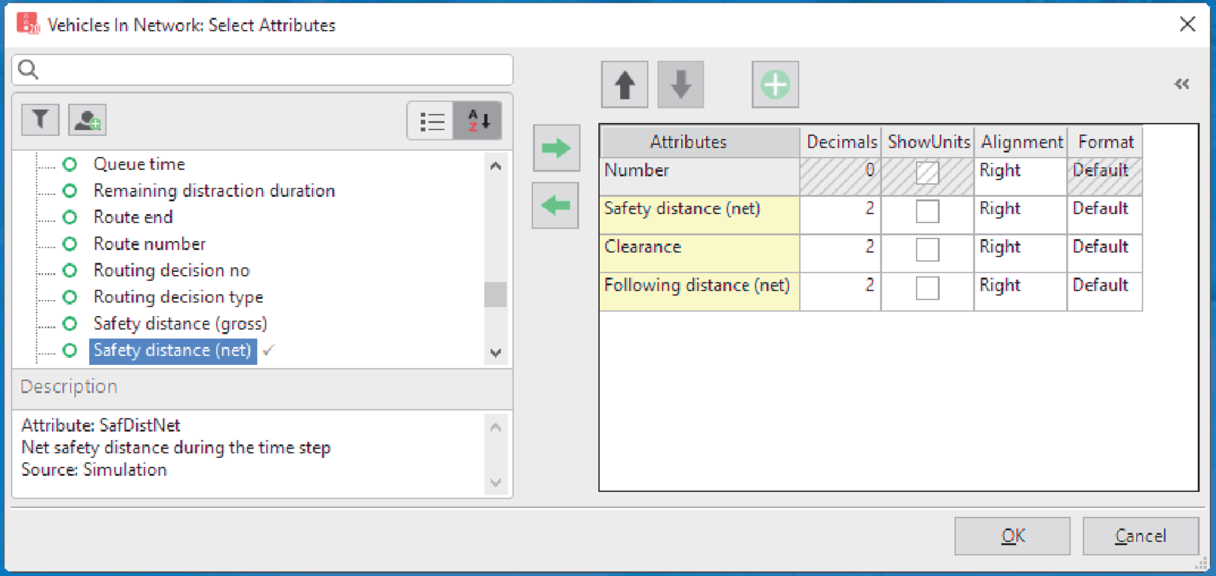
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 723201

Platooning demo

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 723201

New vehicle attributes

- **“Safety distance (net)"**
  is the desired safety distance (front to rear)
- **"Clearance"**
  the distance to the leading vehicle (front to rear)
- **"Following distance (net)"**
  the distance to the relevant interaction object (front to rear)



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CIVITAS SATELLITE

CoEXist

PTV GROUP

the mind of movement

Peter Sukennik
peter.sukennik@ptvgroup.com

#H2020CoEXist
@H2020_CoEXist

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CoEXist

PTV GROUP

the mind of movement

CoEXist project & PTV Vissim

Peter Sukennik

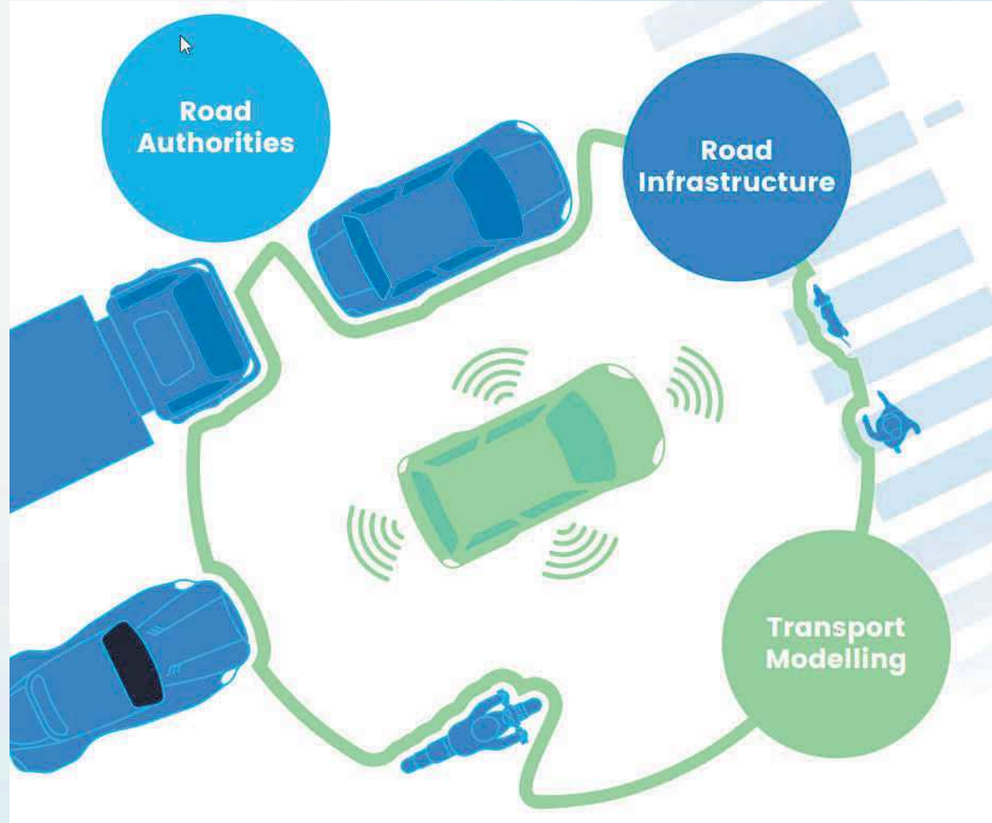
The future is automated

The CoEXist project

- Aim: Prepare cities for the transition phase during which connected and automated vehicles and conventional vehicles will coexist on the roads.

Automation-Ready Transport Modelling

- Integration of CAVs in existing transport modelling tools:
  - Microscopic
  - Macroscopic



www.h2020-coexist.eu

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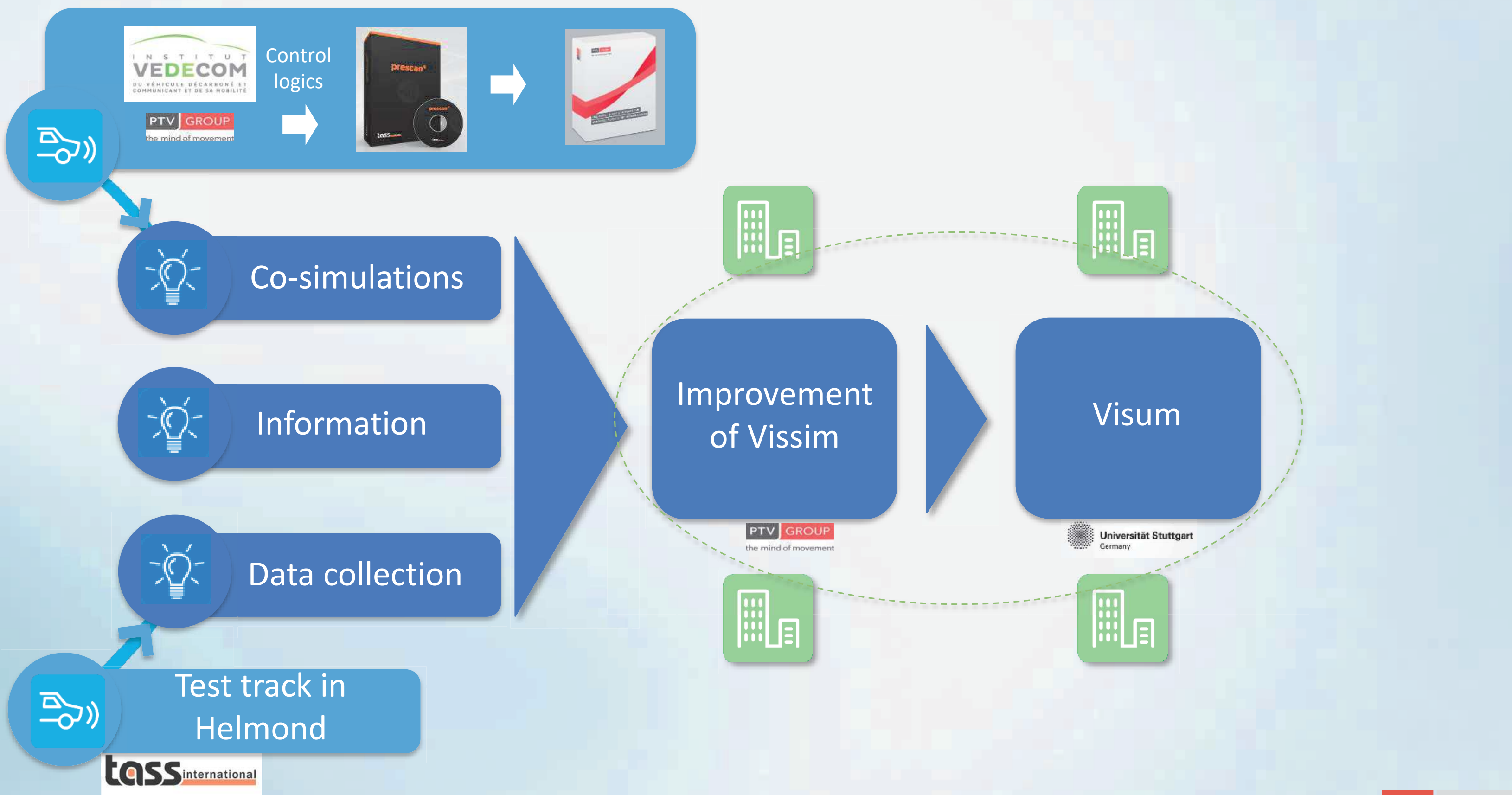
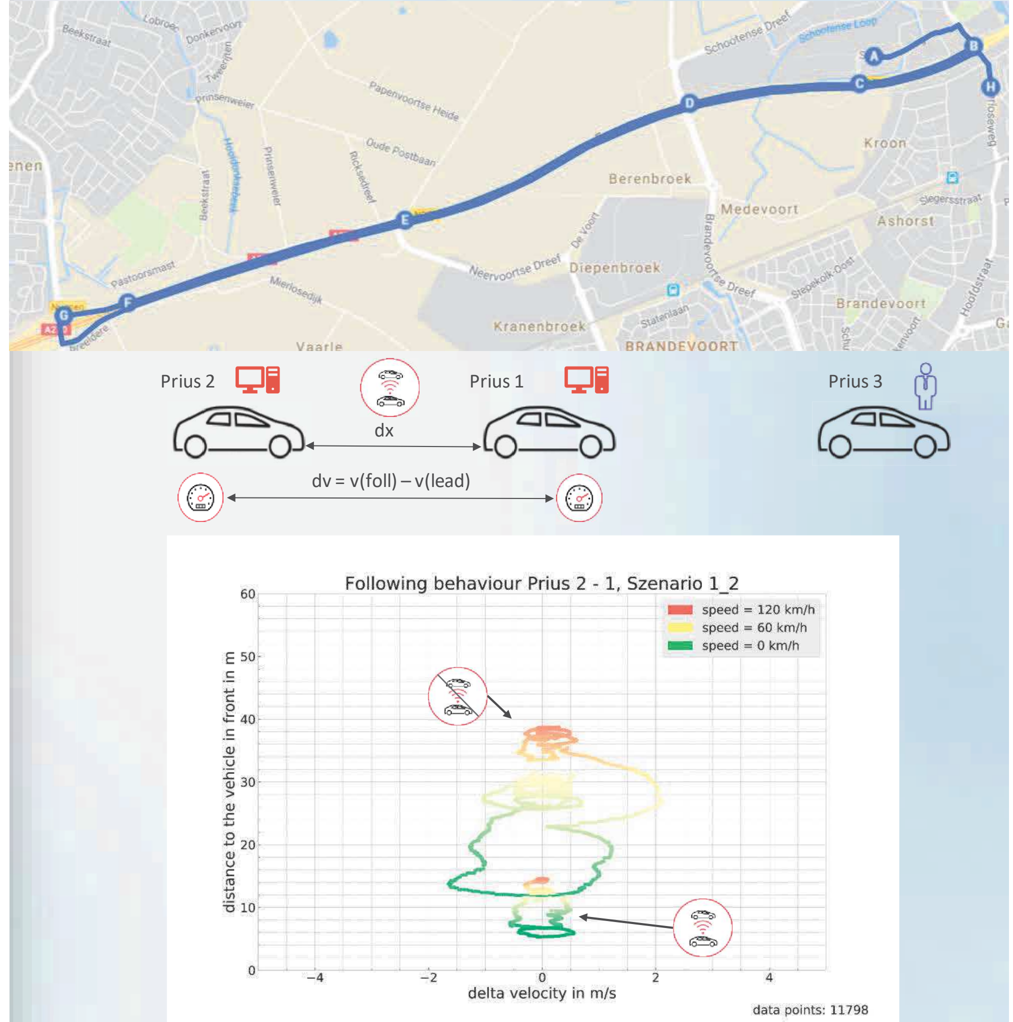
CoEXist approach - Modelling



Data

Collected on test-track in Helmond

- Linear deterministic relationship headway-speed with C2C communication.
- Almost linear relationship headway-speed when following manually driven car or AV without C2C communication.
- Oscillations during the following process are small and without much variance
- With C2C communication the test vehicles were able to drive safely with 0.6- or 0.3-second headway
- Large safety distance in driveaway behaviour when there is no communication.
- No stochastic variation in driveaway behaviour.



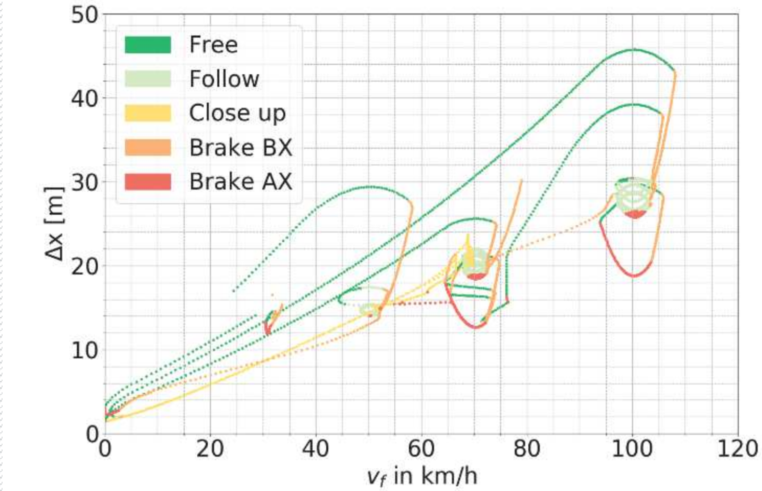
New PTV Vissim features

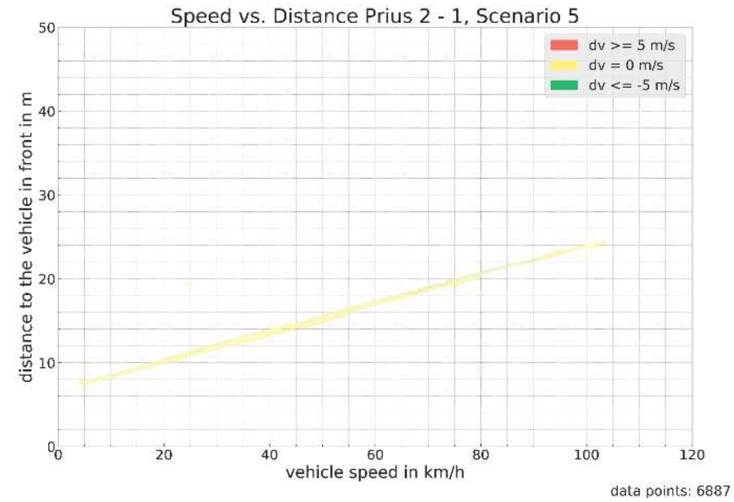
Switching off implicit stochastic

Internal behavior model integrates several stochastic values indicating the spread of human behavior:

- the risk acceptance,
- the ability to estimate distance and speed differences,
- the precision when operating the throttle and braking pedals.

For AVs, deterministic values for these parameters can be assumed.



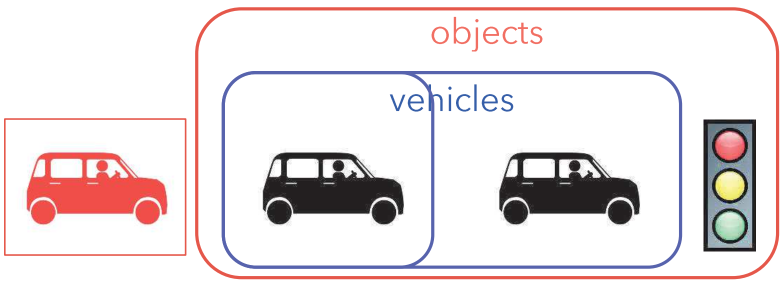


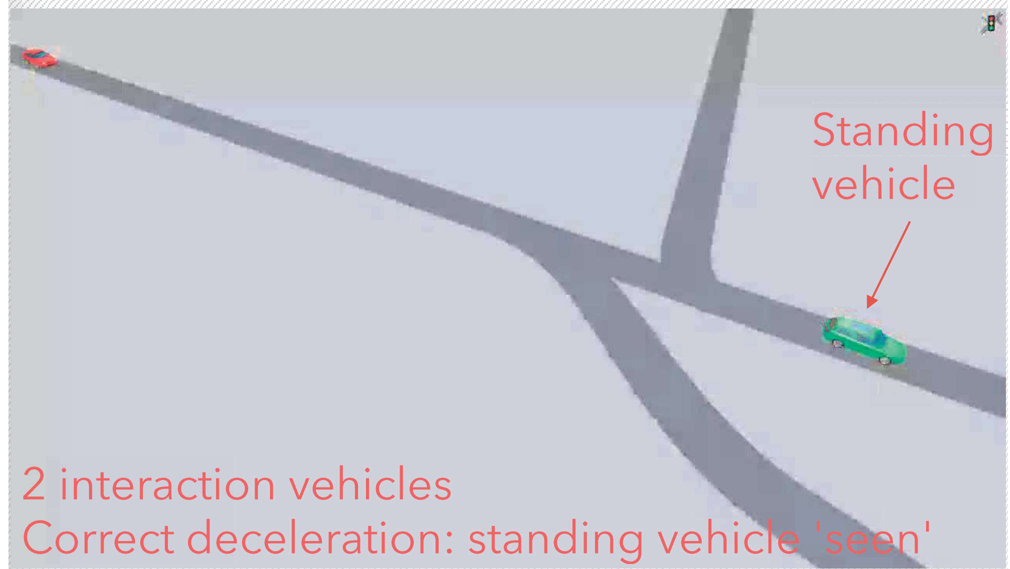
New features

Sensors/Equipment limitations

- Idea: an automated vehicle can see the signals ahead, but only one (or two…) vehicle(s) in front of itself because the sensors cannot see through the leading vehicle

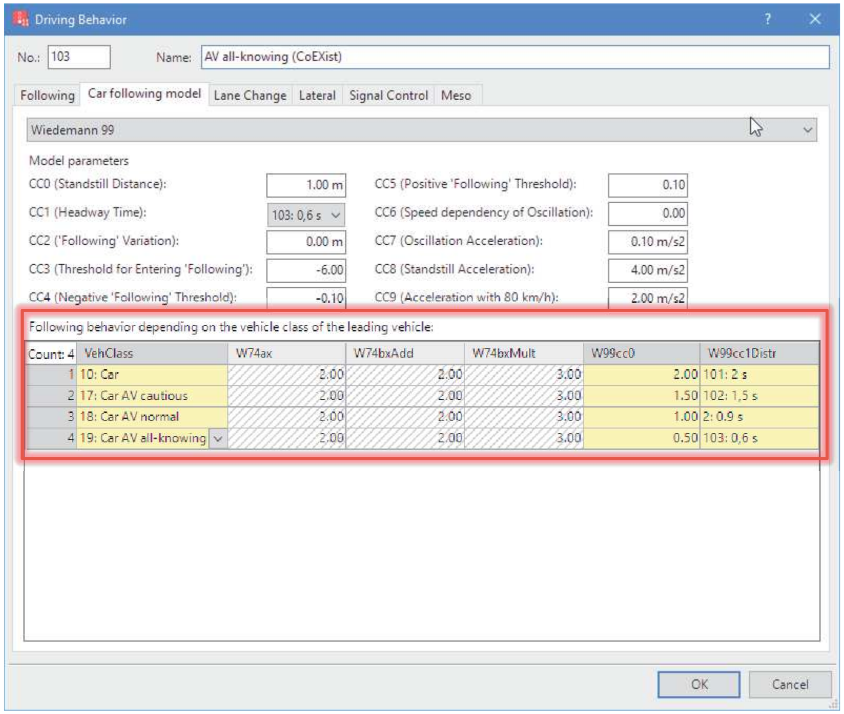
- Number of interaction objects
- Number of interaction vehicles



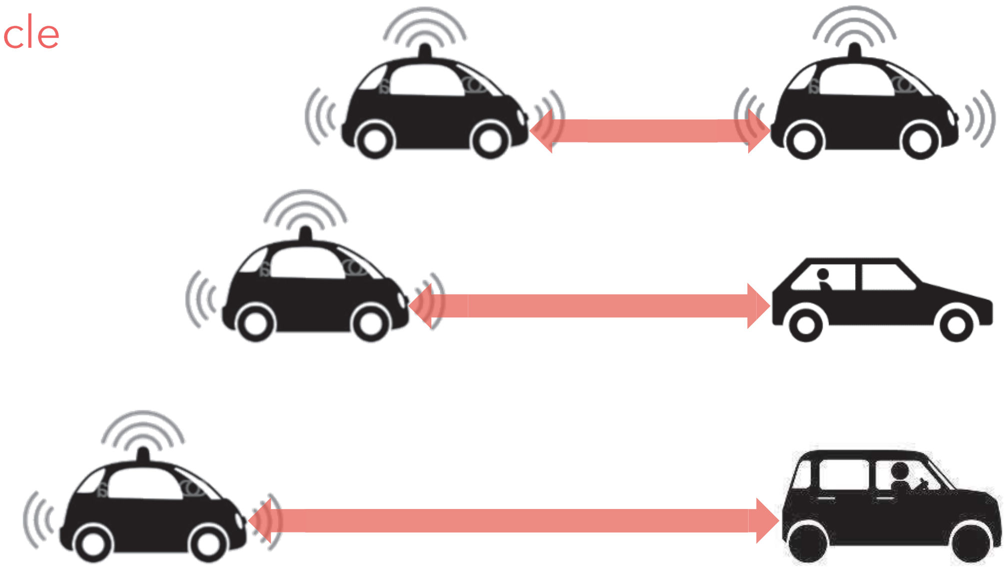


New features

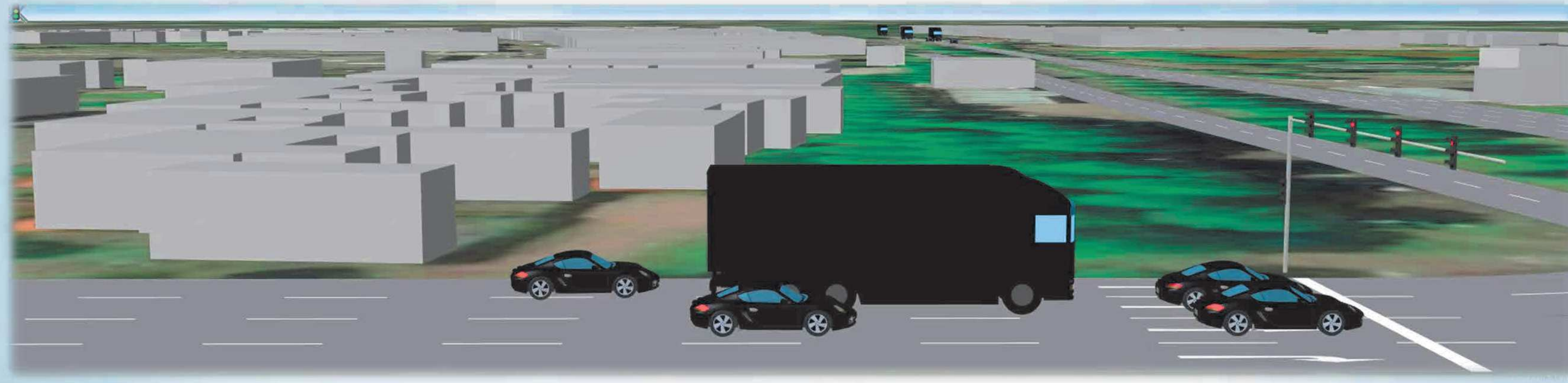
Headway Based on Class of Leading Vehicle



Count: 4	VehClass	W74ax	W74bxAdd	W74bxMult	W99cc0	W99cc1Distr
1	10: Car	2.00	2.00	3.00	2.00	101: 2 s
2	17: Car AV cautious	2.00	2.00	3.00	1.50	102: 1,5 s
3	18: Car AV normal	2.00	2.00	3.00	1.00	2: 0.9 s
4	19: Car AV all-knowing	2.00	2.00	3.00	0.50	103: 0,6 s



Platooning



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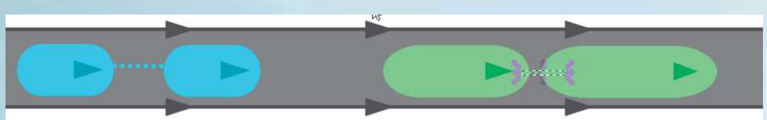
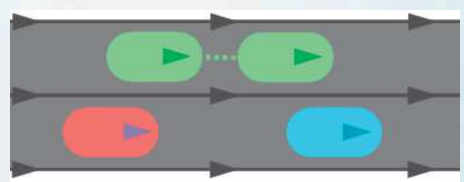
- New driving behavior attributes



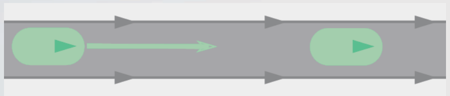
Vehicle class-specific



Lane-specific (new)

Platoon Life Essentials

Joining



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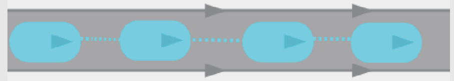

- No lane changes
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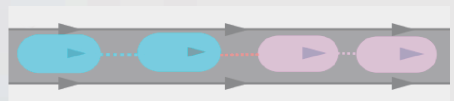
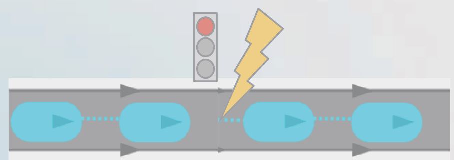
- Limited acceleration change

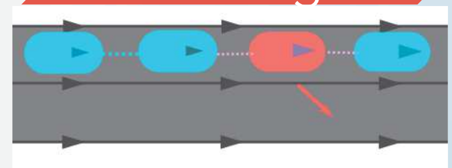


- Change of parameters



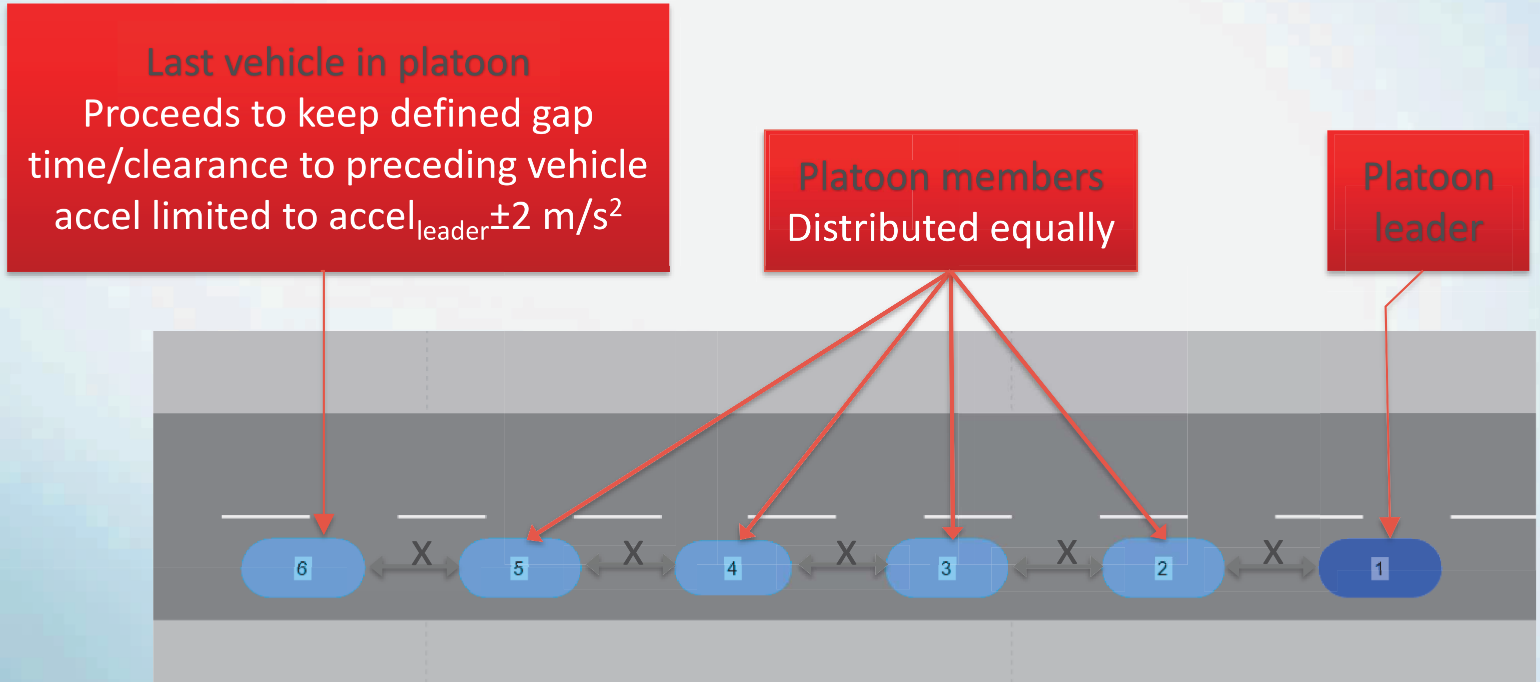
- Split platoon at red signals

Leaving



- Increase distance (before and behind)
- Split platoon

Platoon stability



No simulation of communication process itself: no packet sending or dealing with latency

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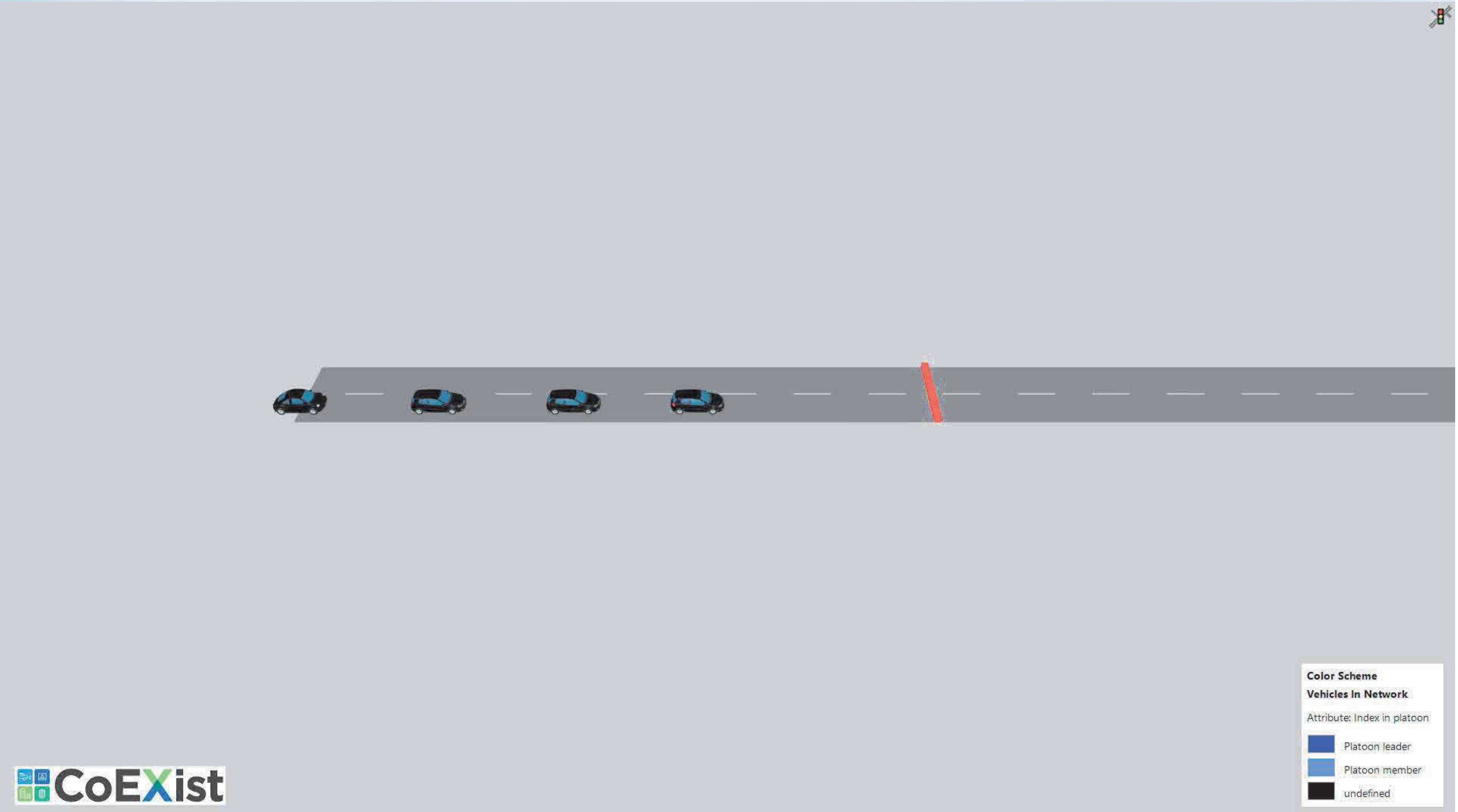
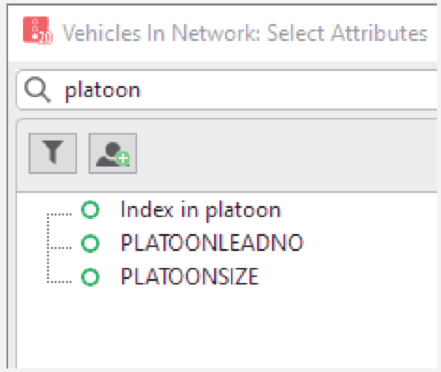
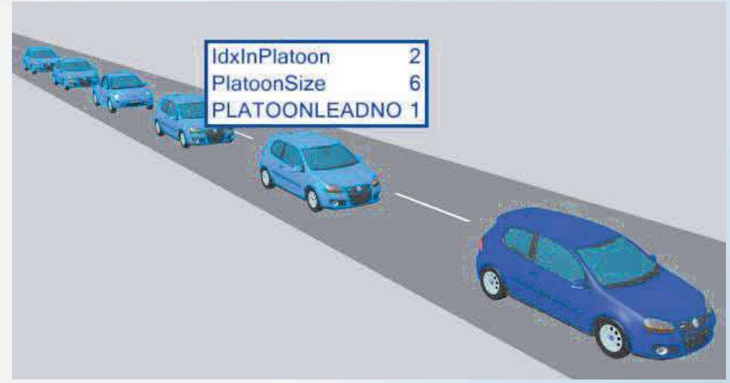

CoEXist
Color Scheme
Vehicles In Network
Attribute: Index in platoon
Platoon leader
Platoon member
undefined

Platoon attributes





- Index in Platoon (IdxInPlatoon)

  Position within the platoon

Since PTV Vissim 2020.00-07:

- Platoon Leader Number (PlatoonLeaderNo)

  If a vehicle is a member of a platoon, this attribute is set to the vehicle number of the platoon leader. Otherwise, it is empty.

- Platoon Size (PlatoonSize)

  If a vehicle is a member of a platoon, this attribute contains the total number of vehicles in the platoon. Otherwise, it is empty.

Modeling framework

Transition period is discretized into three stages

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 ever causing accidents.

Modeling framework

Main uncertainty parameters considered for the experimental design

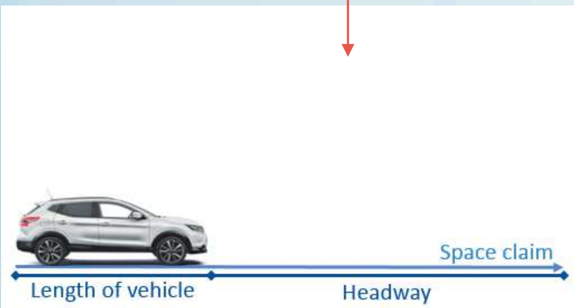
Driving Logic	AV Class	Stage of CoEXistence	Road Environment	Type of vehicles
• Rail-safe • Cautious • Normal • All-knowing	• Basic • Intermediate • Advanced	• Introductory • Established • Prevalent	• Motorway • Arterial • Urban street • Shared space	• Cars • Trucks • Buses & minibuses

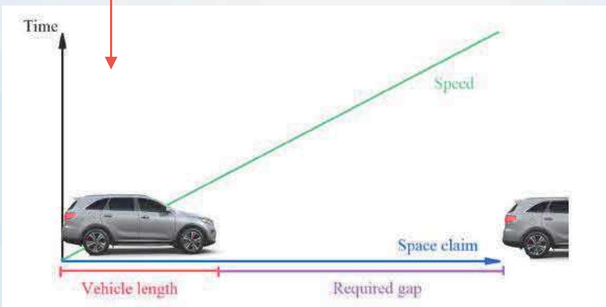
Example relationships between AV-class, driving logics and operational design domain

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

Impact Assessment

CoEXist Hybrid 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.





CoEXist Use Cases

Gothenburg, Sweden

- Shared space
- Accessibility during long-term construction works

Helmond, the Netherlands

- Signalised intersection including peds 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
- Impact of driverless car- and ridesharing services

CoEXist

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the mind of movement

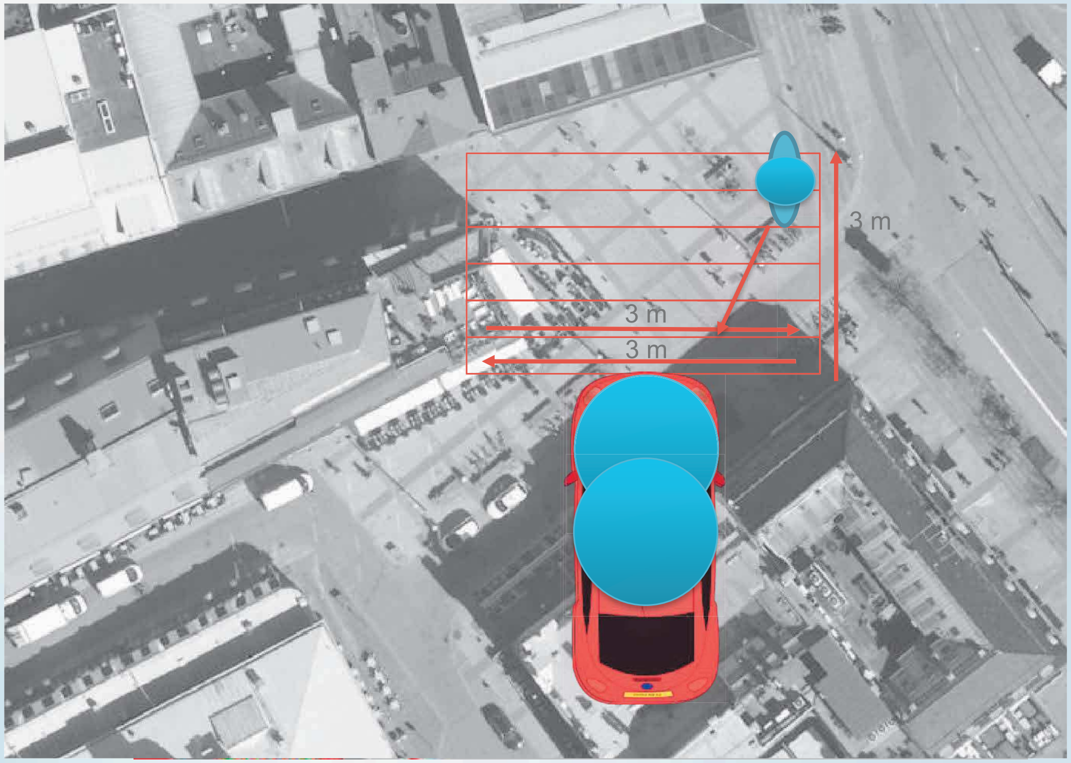
Brief description

Kungstorget Gothenburg

- Peak volume of 2946 pedestrians
- Peak volume of 50 vehicles

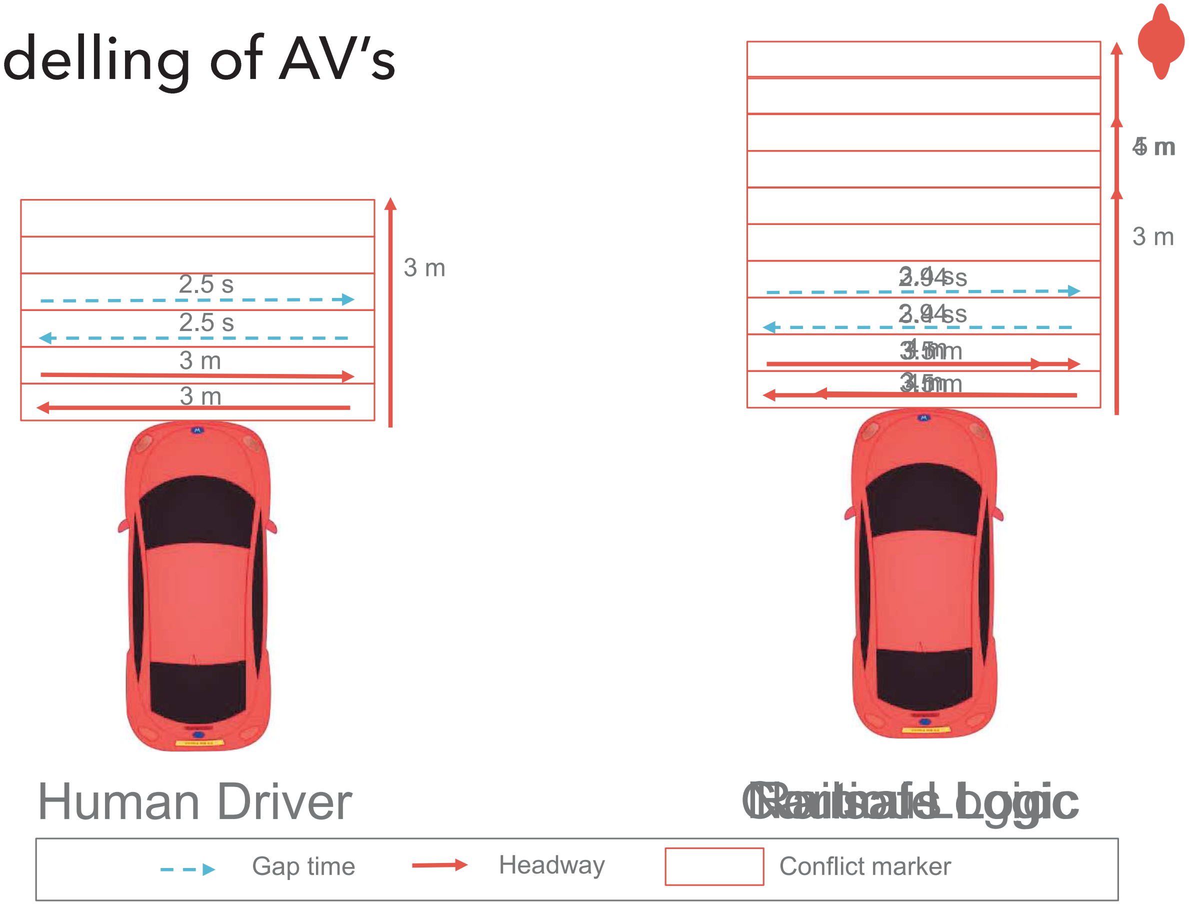
Modelling approach

- Gibb (2015) adapted, needs scripting
- Many narrow links define the shared space area
- Lots of priority rules control behavior of vehicles towards pedestrians
- Different parameters for conflicts depending on the driving logic
- Double representation: pedestrians react to vehicles as if they were large pedestrians



vti iman.pereira@vti.se

Modelling of AV's



10 m

APIs improvements

Driving simulator interface:

- **Automatic interpolation** of Vissim vehs/peds world coordinates, orientations and speeds between Vissim

Driving Simulator Interface
allows connecting Vissim to a driving, cycling or walking simulator (DS).

That DS can either be simulator hardware used by a human or a piece of software representing the algorithms of a CAV or multiple CAVs.

from the center of the front end of a simulator vehicle or pedestrian.

External driver model:

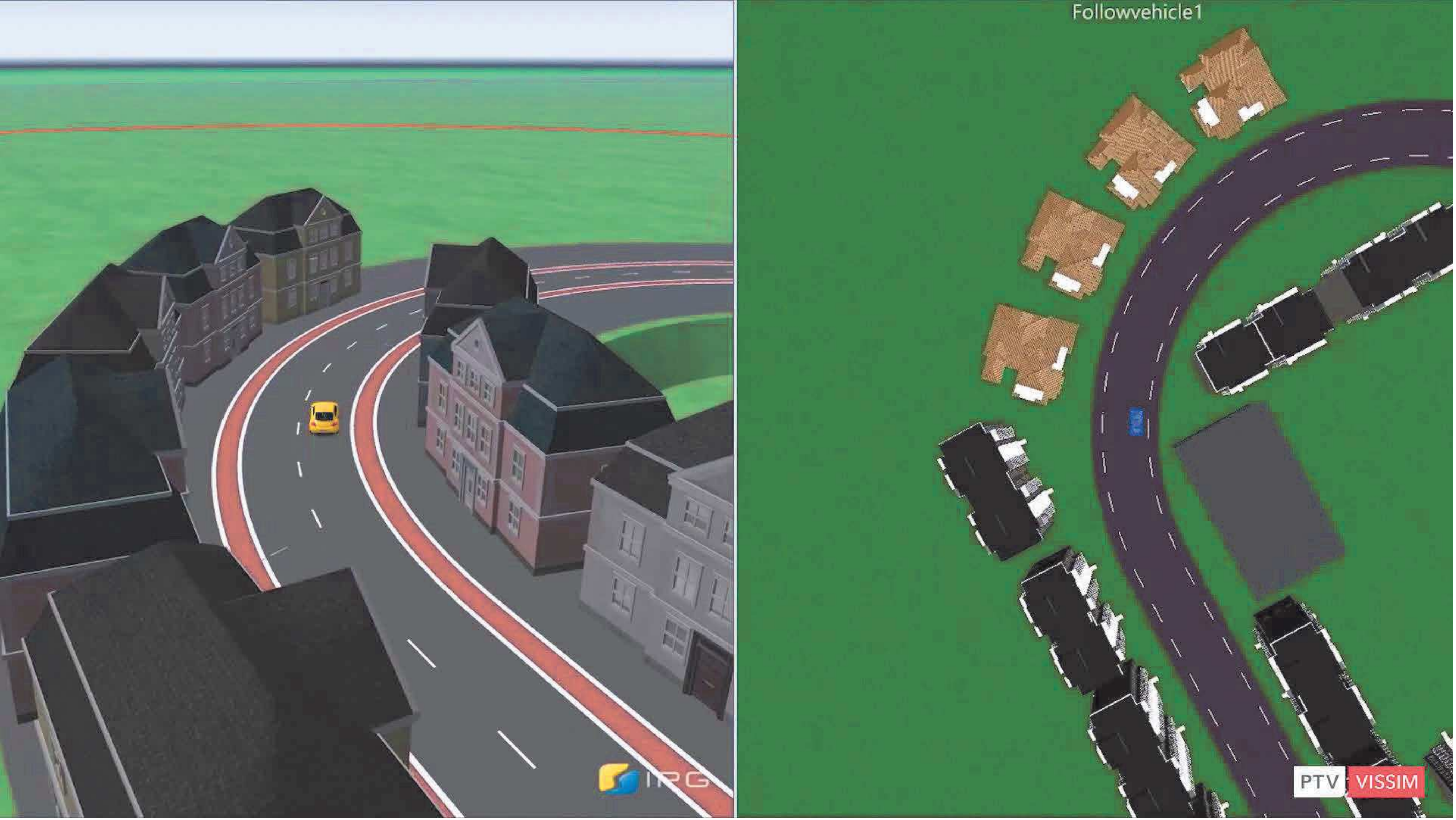
- External driver model DLLs **may be used now in multithreaded simulation** runs if all DLLs confirm that they support multithreading.

External DriverModel interface

provides the option to replace the internal driving behaviour by a fully user-defined behaviour for some or all vehicles in a simulation run.

DriverModel.DLL as well.

- **The polyline** of the current lane of the ego vehicle (along its route/path, within the visibility distance) **is passed to the DLL as well**.


Followvehicle1
PTV VISSIM

CoEXist Lessons learnt and recommendations

- 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 vehicles should or will behave).
- Driving logics: much research is ongoing but there are still no fixed rules or standards and high uncertainties.
- CoEXist delivered the tools for a structured approach of assessing future scenarios and handling uncertainties (e.g. automation-ready framework, comprehensive modelling approach and impact assessment methodology).
- Tools developed enable assessment of innovative infrastructure measures, but measures tested show mobility improvements mainly for high automation and penetration levels.
- Use case simulations show potential deterioration of urban mobility, before promised benefits of CCAM are seen: cities should to plan for the 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.

CoEXist

Final Event

~~Milton Keynes UK~~

Registration:

https://www.h2020-coexist.eu/events/final-conference/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Questions?
206
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