PTV VISSIM & CONNECTED AUTONOMOUS VEHICLES
CAV MODELING PRESENTATION OUTLINE

Connected Autonomous Vehicles Context/Overview

CAV Modeling in PTV Vissim

Use Cases and Benefits

A Look Ahead to Mobility as a Service – MaaS
PTV MaaS Accelerator Program
Autonomous Vehicles will create a challenge for transport and network operators in the coming decade.

Prototype Autonomous Vehicles are being tested in many major cities around the world.

Predictions include that half of all vehicles to be ‘fully autonomous’ within the next 7 to 8 years.

The driving behavior of autonomous vehicles will differ from conventional vehicles.

In the short to medium term autonomous vehicles and conventional vehicles will be required to ‘interact’ in the same road space.
## OVERVIEW

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Name</th>
<th>Steering, acceleration, deceleration</th>
<th>Monitoring driving environment</th>
<th>Fallback performance of dynamic driving task</th>
<th>Virtual testing in PTV Vissim</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NO AUTOMATION the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Green Check" /></td>
</tr>
<tr>
<td>1</td>
<td>DRIVER ASSISTANCE the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Green Check" /></td>
</tr>
<tr>
<td>2</td>
<td>PARTIAL AUTOMATION the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Green Check" /></td>
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<td>3</td>
<td>CONDITIONAL AUTOMATION the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Green Check" /></td>
</tr>
<tr>
<td>4</td>
<td>HIGH AUTOMATION the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Green Check" /></td>
</tr>
<tr>
<td>5</td>
<td>FULL AUTOMATION the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Human" /></td>
<td><img src="https://via.placeholder.com/15" alt="Green Check" /></td>
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</tbody>
</table>

Source: Adapted from SAE Standard J3016 (SAE, 2014)
First Audi models network with traffic lights for free-flowing city driving
Dec 8, 2016

- Traffic Light Information is the first true Vehicle-to-Infrastructure (V2I) service by an automobile brand
- The service starts up with variations on the Audi A4 and Q7 in Las Vegas
- Networking is essential for autonomous driving in cities
Autonomous vehicles have the opportunity to:

- Reduce emissions;
- Increase shared mobility
- Increase road safety
- Reduce the cost of travel
- Reduce parking requirements
- Create free time for passengers.

However the timing, uptake and penetration of AV’s remains unclear.

Transportation modeling has an important role to play in simulating the interaction of autonomous and conventional vehicle fleets to plan and manage current and future infrastructure.
CAV MODELING IN PTV VISSIM

Simulation of AVs:
Depiction of movement of all levels of automated cars.

Impact of AVs:
Evaluation of autonomous driving and its effects on the entire traffic flow.

Multimodality:
Simulation of all modes of transportation and their interaction in a single software.

Sound motion models:
Realistic representation of movement of all road users through proven behavior models.

Simulate your city:
Ability to simulate local conditions for cities around the world.

Traffic scenario testing:
Application of standard and customized scenarios, e.g. "City center at rush hour", "Urban freeways with on-/off-ramps" etc.

Evaluation of scenarios:
Monitoring of weather conditions such as rain, fog or snow.

System integration:
Integration of PTV Vissim with any other standard development software.
CAV MODELING IN PTV VISSIM

1. MODEL SET-UP

INPUT OF NETWORK DATA:
- from available standard map data
- adaptors for many standard formats e.g. HERE, Bing, OSM

INPUT OF TRAFFIC DATA:
Traffic composition
- vehicle types, non-motorized, public transportation
- full interaction

Individual behavior settings
- acceleration/deceleration profiles
- speed and distance choice

Calibration
- to real-world data
- insertion of extreme cases and time-dependent events

APPLICATION OF SCENARIOS:
- systematic variation of input
- design of experiments

2. TRAFFIC SIMULATOR

3. EVALUATION

MULTIMODAL TRAFFIC SIMULATION:
KEY USES FOR CAV MODELING IN PTV VISSIM

- Creating a virtual world environment to simulate how AV’s will operate within transportation networks

- Evaluating varying penetration rates of autonomous vehicles, i.e. if 30% of the vehicle fleet is autonomous what effects is there on capacity?

- Testing different features (e.g. adaptive cruise control) of autonomous vehicles to determine which have the most significant effect on traffic flow.

- Understanding the impact on infrastructure, i.e. can road space be reallocated if vehicles follow each other closer.

- Does there need to be an increase in drop off areas outside buildings/ destinations to serve autonomous vehicle users?
CONNECTED & AUTONOMOUS VEHICLES AT SIGNALIZED INTERSECTIONS
CONNECTED & AUTONOMOUS VEHICLES AT SIGNALIZED INTERSECTIONS

North entry: autonomous vehicles (AVs)

East entry: mixed flow (AVs & CAVs)

West entry: conventional cars only

South entry: connected autonomous vehicles (CAVs)

Cycle time: 28 / 60

Average Delay & Current Queue length

PTV GROUP www.ptvgroup.com
CONNECTED & AUTONOMOUS VEHICLES ON FREEWAYS
CAV MODELING IN PTV VISSIM

How to model autonomous vehicles with PTV VisSim?

- Internally: 'Adapting default driving behavior parameters'
- Externally: 'Using one of PTV VisSim’s interfaces'

DriverModel.dll
DrivingSimulator.dll

Car following model
Lane change behavior

Speeds

COM Interface
PTV VISSIM CAV'S - INTERNALLY

- Adapting car following (Wiedemann), lane change and vehicle speed parameters.
- Quick and simple method to model some AV related features within a given network:
  - Lower standstill distances
  - Lower lateral distances
  - Acceleration rates from standstill
  - Create space for merging vehicles
  - Etc.
- Full scenario based evaluations to assess variations in parameters
- No requirement for programming work
- Limited reaction of AV’s to a situation and no car-to-car or car-to-infrastructure simulation
- Possible applications:
  - investigation of the influence of different follow-up distances or acceleration oscillations on traffic flow at constant or varying AV penetration rates.
  - ...
‘External’ modeling of AV’s utilizes PTV Vissim interfaces

Requires programming work

Control logic of the AV must be defined

Three different interfaces available:

- DriverModel.DLL Interface (additional module)
  - Suitable for anyone who wants to simulate any number of AV’s interacting with other vehicles in Vissim.

- DrivingSimulator.DLL interface (additional module)
  - Suitable for anyone who wants to test the interactions between one or many AV’s (simulated by other software) and vehicles and pedestrians in Vissim. Vehicle sensors may be simulated (by other software).

- COM Interface
  - Suitable for anyone who wants to control the AV’s behavior and other processes by their own algorithms.
PTV VISSIM CAV’s – DESCRIPTION OF EXTERNAL INTERFACES

- COM Interface:
  - The COM script has access to all data inside Vissim which can be made visible in a list window -- meaning driving behaviors and vehicle movements can be altered.
  - COM cannot explicitly control the lateral movement of the AV’s, therefore only desired lane changes rather than direct lane changes can be performed.

- Drivermodel.dll Interface:
  - Vissim passes the current state of the vehicle and its surroundings to the .dll which then computes the ‘reaction’ of the vehicles from the user defined parameters.
  - Vissim allows some or all vehicles to be modeled with the user defined drivermodel.dll which can specify all driving behaviors based on AV logic.

- DrivingSimulator.dll Interface:
  - The world coordinate positions, speed, orientation and detection of the CAV are communicated. The vehicle can be moved completely freely inside the network.
  - The AV algorithm has to be complete as all decisions and calculations have to be instructed, i.e. a vehicle must look for and calculate the distance to the car in front before making a decision on what to do next.
## Table 1: CAV Behaviour Modelling in PTV Vissim

<table>
<thead>
<tr>
<th>No.</th>
<th>CAV Behaviour Description</th>
<th>PTV Vissim Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Keep smaller standstill distances.</td>
<td>➤ W74: change W74ax parameter.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➤ W99: change CC0 parameter.</td>
</tr>
<tr>
<td>2</td>
<td>Keep smaller distances at non-zero speed.</td>
<td>➤ W74: change W74ax, W74bxAdd, W74bxMult parameters.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➤ W99: change CC0, CC1, CC2 parameters.</td>
</tr>
<tr>
<td>3</td>
<td>Accelerate faster and smoothly from standstill.</td>
<td>➤ W74: change acceleration functions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➤ W99: change acceleration functions and CC8, CC9 parameters.</td>
</tr>
<tr>
<td>4</td>
<td>Keep constant speed with no or smaller oscillation at free flow.</td>
<td>➤ COM Interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➤ External Driver Model/ Driving Simulator Interface</td>
</tr>
<tr>
<td>5</td>
<td>Follow other vehicles with smaller oscillation distance oscillation.</td>
<td>➤ W74: reduce W74bxMult or set it to 0.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➤ W99: change CC2 parameter.</td>
</tr>
</tbody>
</table>
## PTV VISSIM CAV’S - MODELING (INTERNAL, EXTERNAL)

<table>
<thead>
<tr>
<th>No.</th>
<th>CAV Behaviour Description</th>
<th>PTV Vissim Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Form platoons of vehicles.</td>
<td>COM Interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External Driver Model/ Driving Simulator Interface</td>
</tr>
<tr>
<td>7</td>
<td>Following vehicles react on green signal at the same time as the first vehicle in the queue.</td>
<td>COM Interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External Driver Model/ Driving Simulator Interface</td>
</tr>
<tr>
<td>8</td>
<td>Communicate with other AVs, i.e. broken down vehicle and others avoid it.</td>
<td>COM Interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External Driver Model/ Driving Simulator Interface</td>
</tr>
<tr>
<td>9</td>
<td>Communicate with the infrastructure, i.e. vehicles adjusting speed profile to reach a green light at signals.</td>
<td>COM Interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External Driver Model/ Driving Simulator Interface</td>
</tr>
<tr>
<td>10</td>
<td>Perform more co-operative lane change as lane changes could occur at a higher speed co-operatively.</td>
<td>Switch cooperative lane change;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change maximum speed difference</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change maximum collision time</td>
</tr>
<tr>
<td>No.</td>
<td>CAV Behaviour Description</td>
<td>PTV Vissim Methodology</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>11</td>
<td>Smaller lateral distances to vehicles or objects in the same lane or on adjacent lanes.</td>
<td>- Same lane – change default behavior when overtaking on the same lane.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Define exceptions for vehicle classes.</td>
</tr>
<tr>
<td>12</td>
<td>Exclusive AV lanes, with and without platoons</td>
<td>- Define blocked vehicle classes for lanes, or define vehicle routes for vehicle classes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use COM for platooning.</td>
</tr>
<tr>
<td>13</td>
<td>Drive as CAV on selected routes (or areas) and as conventional human controlled vehicles on other routes; i.e. Volvo DriveMe project.</td>
<td>- Use different link behavior types &amp; driving behavior for vehicle classes; and/or (depending on complexity of CAV behavior).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- COM</td>
</tr>
<tr>
<td>14</td>
<td>Divert vehicles already in the network onto new routes and destinations; i.e. come from a parking place or position in the network to pick up a rideshare app passenger on demand.</td>
<td>- COM Interface (new functionality provided in 9.00-03)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Dynamic Assignment required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Allows access to paths found by dynamic assignment, vehicles can be assigned a new path either when waiting in parking lot or already in the network (if path starts from vehicles current location).</td>
</tr>
</tbody>
</table>
PTV VISSIM – DRIVING SIMULATOR INTERFACE .DLL

- Allows testing of interaction between externally controlled vehicles and vehicles/pedestrians in Vissim.
- All decisions and calculations of externally controlled vehicles have to be instructed and are based on reaction to ‘other’ vehicles in the simulation.
- Vehicle moves through the Vissim network based on simulator instructions, i.e. steering movements, acceleration etc.
- Other vehicles ‘react’ to what the external vehicle is doing.
- Performance of all vehicles can be evaluated and analyzed to determine optimum driving parameters.

During Simulation Run:
- Set Driver Vehicles & Detection
  Position (x,y,z), Speed, Orientation, Activates detectors
- Get Traffic Vehicles & Signal States
  VehID, VehType, Position (x,y,z), Orientation,
  Speed, Leading & Trailing Vehicle, LinkID,
  LinkName, LinkCoordinate, LaneIndex, TurningIndicator,
  SignalGroupID, SignalState, ControllerID

Start Vissim

Driving Simulator DLL
Calculate new position of driver vehicles for next simulation step

Vissim
Simulation step of all vehicles in the network
Vissim +PreScan
U.S. Federal Highway Administration’s Turner-Fairbank Research Center

- Utilizes DrivingSimulator.dll Interface;
- Turner Fairbank Research Centre controlled vehicle embedded into a Vissim microsimulation model of a freeway;
- Vehicle moves through the Vissim network based on how President Obama drives, i.e. steering movements, acceleration, etc.
- All other vehicles in the simulation controlled by Vissim;
- Other vehicles ‘react’ to what the Turner Fairbank Research Vehicle is doing;
- Performance of all vehicles can be evaluated and analyzed to determine optimum driving parameters.

https://www.youtube.com/watch?v=X5ZrWjlCSdM
PTV VISSIM – HUMAN IN THE LOOP
PTV VISSIM – HUMAN IN THE LOOP
DriveMe Volvo project tests the infrastructure and typical traffic situations suitable for autonomous vehicles on Gothenburg’s city ring road.

Large scale autonomous driving pilot project in which 100 self driving Volvo cars will use public roads in everyday driving conditions.

PTV Vissim was used to create the microscopic model of the ring road.

Adjustments to ‘internal’ driving behavior parameters were made to simulate and evaluate specific portion of AV cars in traffic flow.
UK Department for Transport commissioned study to simulate the impacts Connected Autonomous Vehicles (CAV’s) may have on traffic flow and capacity.

- Atkins consultants created a number of Vissim models to replicate conditions across the UK’s trunk road network.

- COM Interface adopted to configure CAV’s to change behavior according to the traffic situation.

- Considered whether CAV’s would be more cautious in their behavior and the impact this has on road capacity.
CAV MODELLING IN VISSIM – USE CASES

- CoExist EU Project;
- PreDRIVE C2X;
- CHAUFFEUR truck platooning;
- Various Automotive Manufacturers;
- INVENT for ADAS development;
- eCoMove for emissions reduction.
THE BENEFIT OF TRANSPORTATION MODELING & SIMULATION

- A Virtual Environment for CAV’s to answer operational strategy questions:
  - Testing CAV & MaaS vehicles’ impact on Traffic
  - Technology testing by running software & hardware in the loop
  - Cost effective compared to real world test bed
  - Flexible to quickly undertake and assess unlimited scenarios
  - Determine acceptable CAV operation for deployment

- Creating a platform for roundtable discussions between:
  - Vehicle Manufacturers
  - Technology Suppliers
  - Infrastructure Designers
  - Transportation Operators
TOMORROW’S BUSINESS MODEL: SIGNIFICANT SHIFT TO SHARED MOBILITY AND MOBILITY AS A SERVICE (MAAS)
TOMORROW’S BUSINESS MODEL: SIGNIFICANT SHIFT TO SHARED MOBILITY
SOFTWARE FOR MAAS
TOMORROW’S BUSINESS MODEL: SIGNIFICANT SHIFT TO SHARED MOBILITY

KEY QUESTIONS MOVING TOWARDS A CAV & MAAS

WHAT DOES THE INTRODUCTION OF SHARED MOBILITY & CAV’S MEAN?

- Reduce Accidents
- Reduce Emissions
- Reduce parking requirements
- Improve congestion & reliable journey times
- Reallocate road space to other users
- Enhance mobility for all
- Free up commuter time
- Additional autonomous modes
TOMORROW’S BUSINESS MODEL: SIGNIFICANT SHIFT TO SHARED MOBILITY

KEY QUESTIONS MOVING TOWARDS A CAV & MAAS FUTURE

WHAT ARE THE KEY QUESTIONS AROUND THE INTRODUCTION OF SHARED MOBILITY & CAV’S IN CITIES?

Potential for increase in miles traveled

Impact of varying AV rates of penetration across ‘mixed’ traffic

How will AV’s be programmed to drive?

What levels of infrastructure alterations are required, who will provide the investment?

Who will provide the required regulation?

How will various ride-share, CAV’s operating systems within a city?

How will curbside pick up and drop off operate?
TOMORROW’S BUSINESS MODEL: SIGNIFICANT SHIFT TO SHARED MOBILITY

FURTHER REVIEW OF CHALLENGES FOR CAV & MAAS

STRATEGY

HOW CAN CAV TARGET’S BE ACHIEVED OPERATIONALLY?

Designated CAV Only Zones

- Targeted locations suitable for CAV operations e.g. Downtown
- No mix with Non CAV’s
- Potentially large trip share due to ‘short trips’
- Limited area for infrastructure upgrades
  - How do people travel to ‘CAV Only Zone’?

All Areas

- How will CAV’s and Non CAV’s interact on the road network and effect capacity?
- Does the current road infrastructure support CAV’s requirements?
- Would dedicated lanes be required for CAV’s?
- Support a larger travel demand due to coverage

Transport Modes

- Which travel modes (taxis, metro, bus, private vehicle) has the biggest impact on % target?
- Which travel mode has the biggest impact on congestion/ journey time for overall system?
- Which travel mode most appeals to the population?

Vehicle Operation

- How will vehicles be programmed to drive (safety, speed, emissions, capacity) and what will the impact on the overall network be?
- Who will determine vehicle driving behavior?
- How will vehicles choose routes through cities and who controls them?
TOMORROW’S BUSINESS MODEL: SIGNIFICANT SHIFT TO SHARED MOBILITY

HOW WILL CAV’S & MAAS OPERATE IN CITIES?

- CAV movements:
  - Driving Behavior
  - Where is Platooning accepted;
  - Vehicle to Vehicle Communication;
  - Hardware in the loop

- Infrastructure Requirements:
  - Vehicle to Infrastructure (Communication)
  - Configuration of intersections
  - Signal Controlling
  - Parking/ Drop Off Areas

KEY AREAS OF FOCUS

- Operational Control of CAV’s:
  - External Navigation (who determines appropriate routing)
  - Repositioning of empty vehicles
PTV MAAS ACCELERATOR PROGRAM

- Complete portfolio of component technologies for planning MaaS operations all the way to operating and managing MaaS in any given city around the world – designed for automotive OEMs and city governments alike.
PTV MaaS Modeller allows automotive OEMs to do the plans for their MaaS business operations

- including the identification of the optimum size of their vehicle fleet, types of cars to be used or the waiting times.

Furthermore, the PTV MaaS Modeller is of great benefit to city governments

- in need to prepare their city business plans for how does MaaS interact with their current plans for transportation and public transportation.
PTV MaaS Simulator looks at the detailed interaction of pedestrians and bicycles combined with autonomous vehicles and shared mobility services.
PTV MAAS OPERATOR

- PTV MaaS Operator is the component for demand management and route optimization both in real-time as well as offline.
- Enables vehicles operators to run and manage their vehicle fleets in an efficient manner concurrently.
- Intelligently serves mobility users by bringing them with utmost convenience from the point of origin to their desired destination.
PTV MaaS Controller is a component for the integration into a city’s mobility operation system enabling efficient traffic management, public transport operations and network planning.
PTV MAAS ACCELERATOR PROGRAM

- Continued development and application

- More to come…stay tuned!
QUESTIONS

Contact Information:

Bill Cisco, P.E.
bill.cisco@ptvgroup.com
503.297.2556

ptvgroup.com
18th Annual North America
PTV Vision Traffic User Group Meeting
October 11-12, 2017
San Francisco, California