MAVEN

(Managing Automated Vehicles Enhances Network)

Automated driving in an urban environment

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Braunschweig, Germany

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

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General Information

- **Website**
  - ✓ www.maven-its.eu
- **Duration**
  - ✓ 36 months (Sept ’16 – Aug ‘19)
- **Funding**
  - ✓ ~3M€ under EC H2020 programme
- **Partners:**
  - ✓ From five countries: DE, NL, CZ, BE, UK

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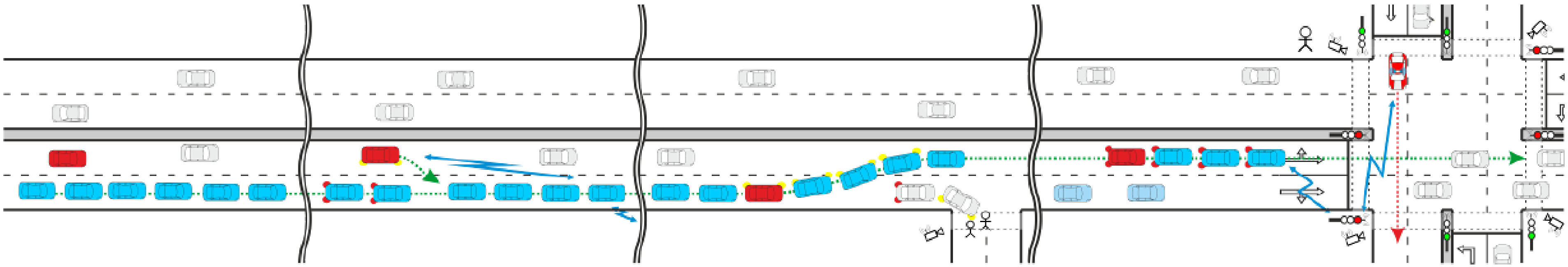
Project summary

- MAVEN will develop management regimes for highly automated driving in urban areas.
- Road infrastructure will be able to monitor, support and orchestrate vehicle and VRU movements to guide vehicles at signalized intersections and corridors in urban areas.

Main objectives

- Increase safety with collective perception
- Increase efficiency by exploiting possibilities of automated driving



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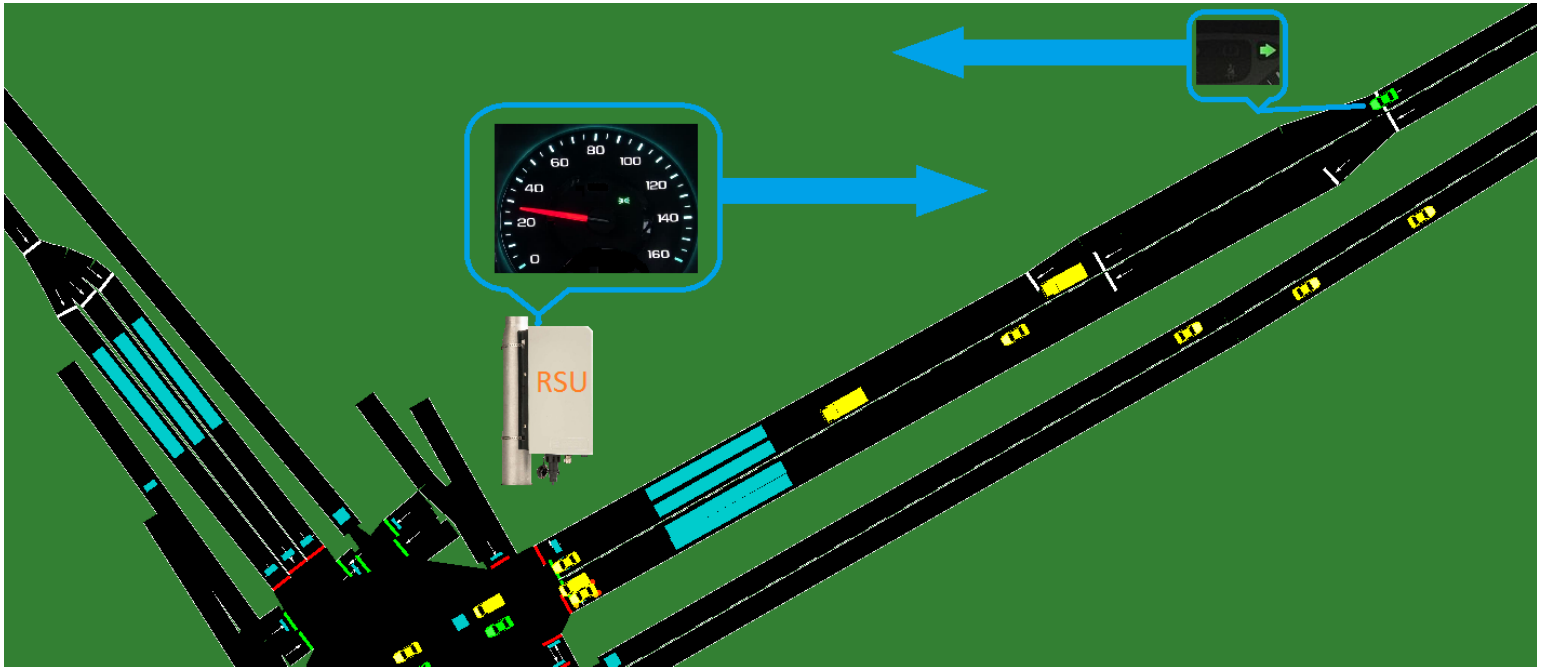
MAVEN I2V signal negotiation



- **Vehicle information (1)**
  - Vehicle and/or platoon transmits expected route, desired speed, platoon size, etc.
- **RSU / TLC re-optimize control strategy (2)**
  - Based on received information there can be a new optimum,
  - update SPATEM with new signal timing and speed advice and lane information
- **Vehicle feedback(3)**
  - Vehicle and/or platoon communicates if suggestion can be executed
  - TLC can take this into account by not making signal timing changes anymore

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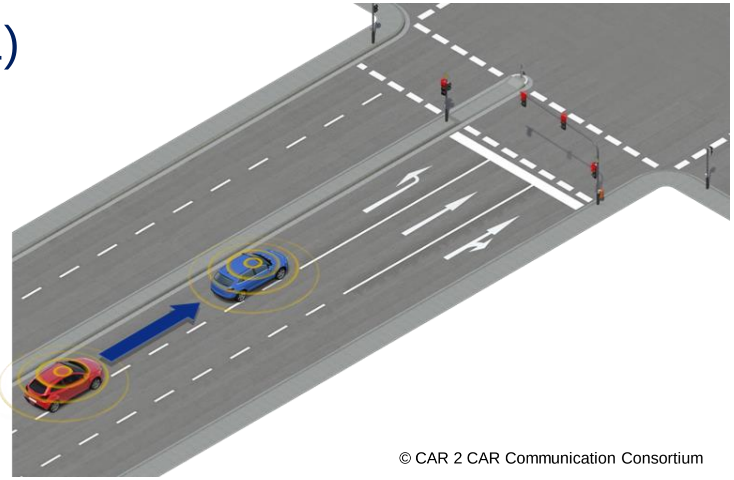
MAVEN platooning

(1)



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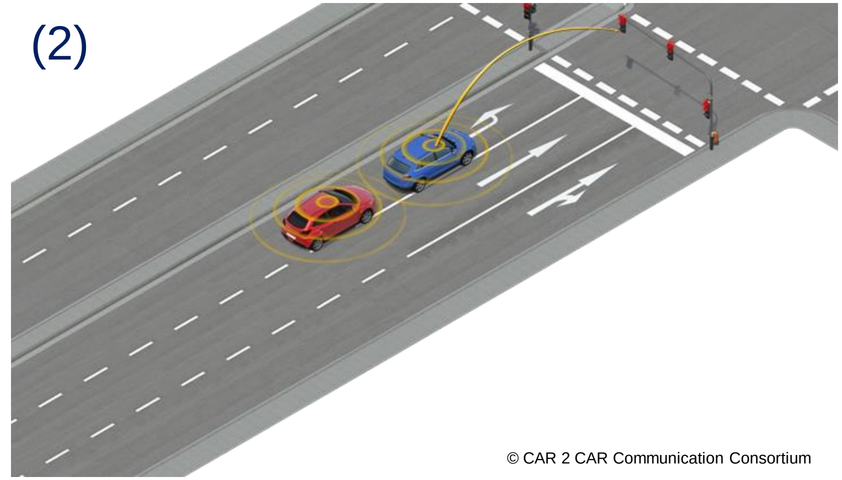
(2)



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- **Mix between distributed and centralized approach**
  - Based on common distributed algorithm and V2V exchanged info, individual vehicles form platoons and manage their operation (joining, leaving, etc.) (1)
  - Yet, platoon leader has the central role of communicating platoon properties to the infra (2)
- **Use of 2 parallel radio channels**
  - One for advertising vehicle and/or platoon characteristics to other vehicle or infra
  - The other, to transport platoon control and management info

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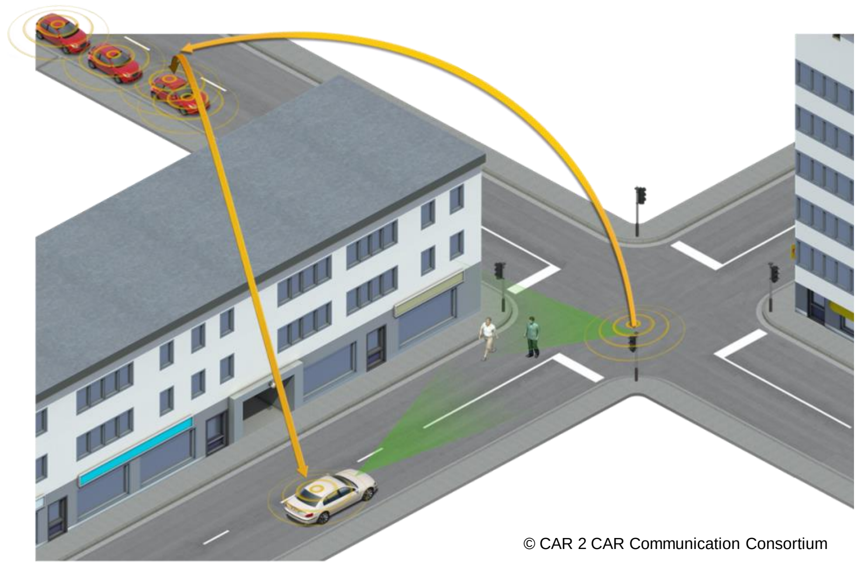
Inclusion of conventional traffic and VRUs



- **Use of cooperative sensing for improved detection and reaction**
  - ✓ Both vehicles and infra can detect and share info about non-cooperative road users
  - ✓ Improved awareness used to adapt vehicle trajectory for ensuring increased safety
- **Managemement of emergency situations**
  - ✓ Vehicles in platoon keep monitoring the environment and controlling the system all the time to possibly undertake emergency (automated) reactions

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Extension of standard message sets

- **Message sets defined for V2X communication**
  - ✓ Collective Perception Message (CPM)
  - ✓ Lane Advice Message (LAM)
  - ✓ Extensions to Cooperative Awareness Message (CAM)
- **Standardization**
  - ✓ Alignment with Car2Car Consortium about CPM
  - ✓ Results are brought into ETSI for standardization

- **… do not hesitate to contact us for:**
  - ✓ Share ASN.1 definitions
  - ✓ Design details
  - ✓ Etc.

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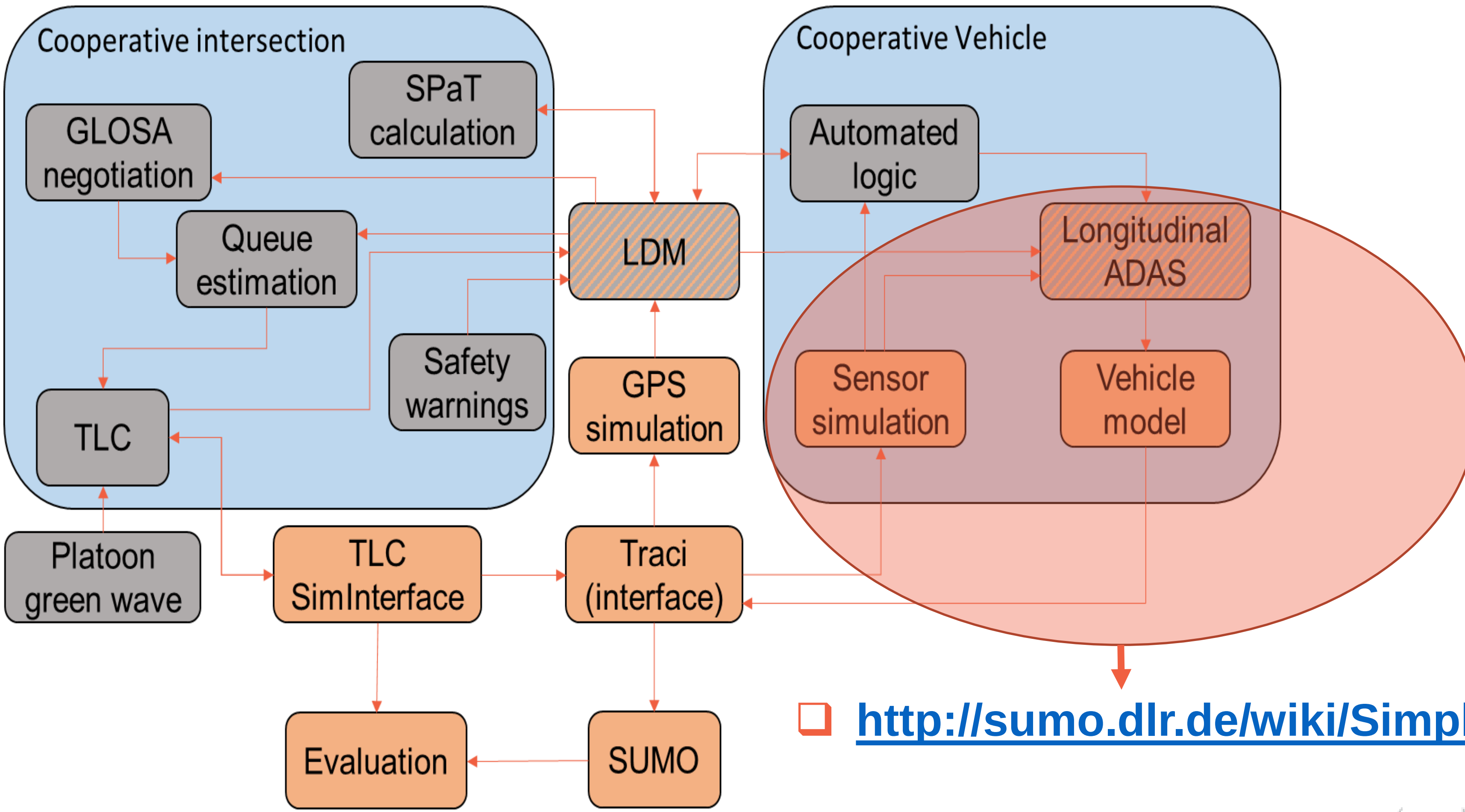
Simulation Architecture for automated vehicles



- http://sumo.dlr.de/wiki/Simpla

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Simulation Architecture for automated vehicles

- **Open Local Dynamic Map (LDM) interface**
  - Regular SPaT and CAM data
  - Lane level accurate vehicle positions (extended CAM or sensor)
  - Extended vehicle status: speed advice, platoon status, following distance, intended route
  - Queue information

- **True cooperative simulation**
  - Information from vehicles is processed in traffic light controller
  - Vehicles follow speed advice in simulation
  - Chance for impact assessment at high penetration rates

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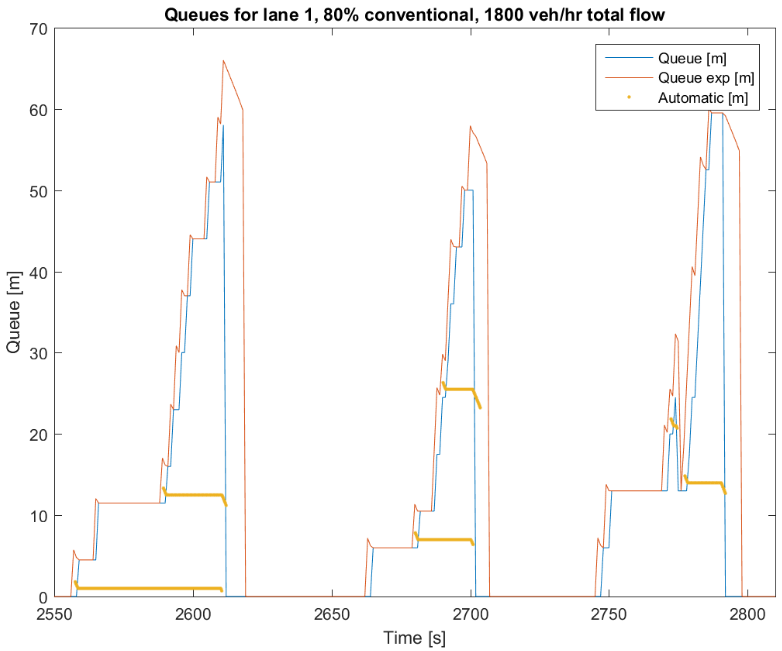
Enhanced queue modelling

- ❑ **Queue length vital for GLOSA**
  - ✓ Arrive at the stop line when queue is discharged instead of light turning green
- ❑ **Improved traffic light performance**
  - ✓ Better information allows optimizer to get closer to true optimum
- ❑ **Various information sources**
  - ✓ Vehicle destination information
  - ✓ Following distance
  - ✓ Infrastructure sensor counts
  - ✓ Infrastructure sensor occupancy



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Plan stabilization for adaptive control

- **Plan stabilization with flexibility required for MAVEN use cases**
  - ✓ Unstable plan leads to unnecessary acceleration/deceleration
  - ✓ Drivers will loose trust in system with instability
- **Cost function designed for adaptive control**
  - ✓ Exploits possibility to fixate the start of only one signal group
  - ✓ Cost function parameter allows applying policy preferences of road operator rather than a magic number of x seconds
- **Patent granted for plan stabilization solution**

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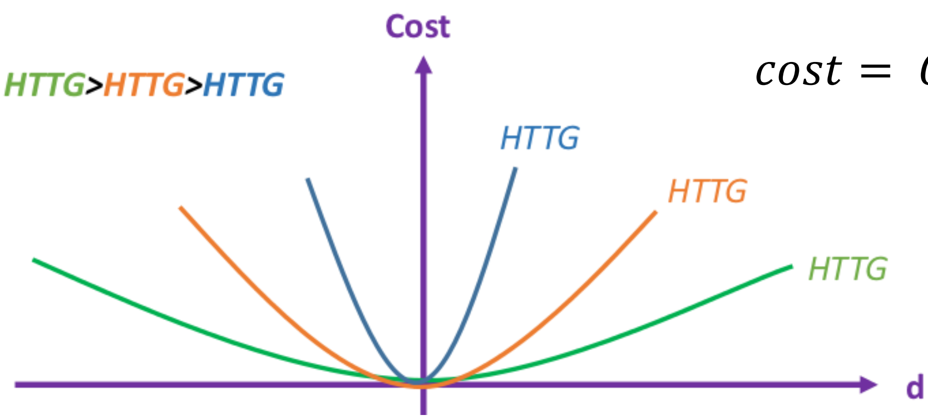
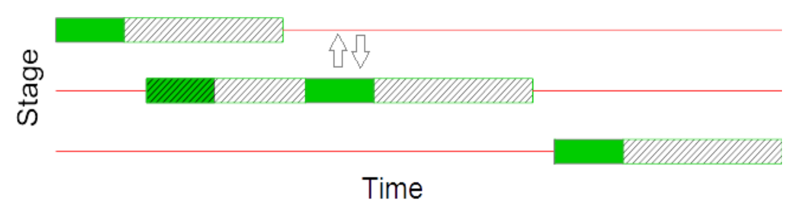


$$cost = C\frac{d^2}{HTTG}$$



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Plan stabilization evaluation

- **Log prediction and compare to actual switch**
- **Mean Square Error (MSE)**
  - ✓ Bias towards errors at high Time To Green (TTG)
- **Mean Relative Error (MRE)**
  - ✓ Divides absolute error by remaining TTG
  - ✓ Good measure for speed advice performance
- **Perceived Change (PC)**
  - ✓ New measure to estimate drivers perception
  - ✓ Indicator for frequent acceleration/deceleration

$$pc = \left. \sum_{t=1}^{T} \frac{\alpha\, TTG_{t-1} - TTG_t}{min(TTG_{t-1}, TTG_t)} 100\% \middle/ \sum_{t=1}^{T} \alpha \right.$$

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Infrastructure Improvements: Results of plan stabilization

- **Best of both worlds: flexible and stable**
  - ✓ Tested on single intersection with 1 stabilized signal group
  - ✓ More stable and better traffic efficiency compared to current state-of-the-art
  - ✓ Policy setting changes behaviour

Scenario	Impact(s)	Delay(s)	Stops	GLOSA(%)	MSE(s^2)	MRE(%)	PC(%)
Static	43.2	36.7	0.81	25	0	0	0
Actuated	36.3	29.6	0.84	19	182	84.67	7.62
Adaptive	32.7	27.0	0.72	46	47	26.38	5.65
Semi-fixed	37.4	31.0	0.80	27	62	41.89	3.82
Stabilized	32.7	27.0	0.71	53	17	15.01	3.52
Stabilized x5	35.6	29.7	0.73	51	22	7.95	2.66

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Pilot site Helmond

- **Large test site with 20+ 802.11p RSUs installed**
  - ✓ One intersection approach with TraffiRadar car-following detection
  - ✓ Adaptive traffic control to introduce autonomous vehicles into the policy framework
- **Hyundai vehicle**
  - ✓ Based on series produced Ioniq
  - ✓ Sensor setup: mono-camera, front+corner radars, front+rear LiDAR, 802.11p V2X
  - ✓ MAVEN-compatible AD architecture: data fusion, vehicle control and path planning

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Pilot site Braunschweig

- **Application Platform for Intelligent Mobility (AIM) test site**
  - ✓ Stereo video detection with radar and hemispherical dome camera's
  - ✓ Tostmannplatz intersection has 4 controlled approaches
  - ✓ Vehicle actuated control
  - ✓ RSU and parallel SUMO model for vehicle position modelling
  - ✓ HYU and DLR test vehicles
- **Two DLR vehicles**
  - ✓ eGolf and Passat GTE
  - ✓ Sensor setup: mono-camera, 6x radars, 4x LiDAR,
    802.11p V2X, DGPS, Ultrasonic
  - ✓ MAVEN-compatible AD architecture:
    data fusion, vehicle control and path planning

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Test planning

- ❑ **Simulation**
  - ✓ Prague, Greenwich, Helmond, Braunschweig
  - ✓ SUMO: Impact assessment, large-scale applications
  - ✓ DOMINION: Controlled environment, detailed analysis
- ❑ **Closed test sites (Grießheim, Edemissen Air Field, DLR closed track)**
  - ✓ Mobile RSU & TLC
  - ✓ Initial platooning tests up to 3 vehicles
  - ✓ Lane advice and collective perception
  - ✓ Activities from February 2018 to September 2018
- ❑ **Open road tests**
  - ✓ Installation of hardware up to December 2017
  - ✓ Activities from August 2018 to February 2019

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Thank you!

Questions?

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