ÓBUDAI EGYETEM


# Vehicle Informatics
# (Vehicle System Informatics)

## Lectures

## Part 08

(V2X Solutions,
Connected_Cooperative_Mobility)

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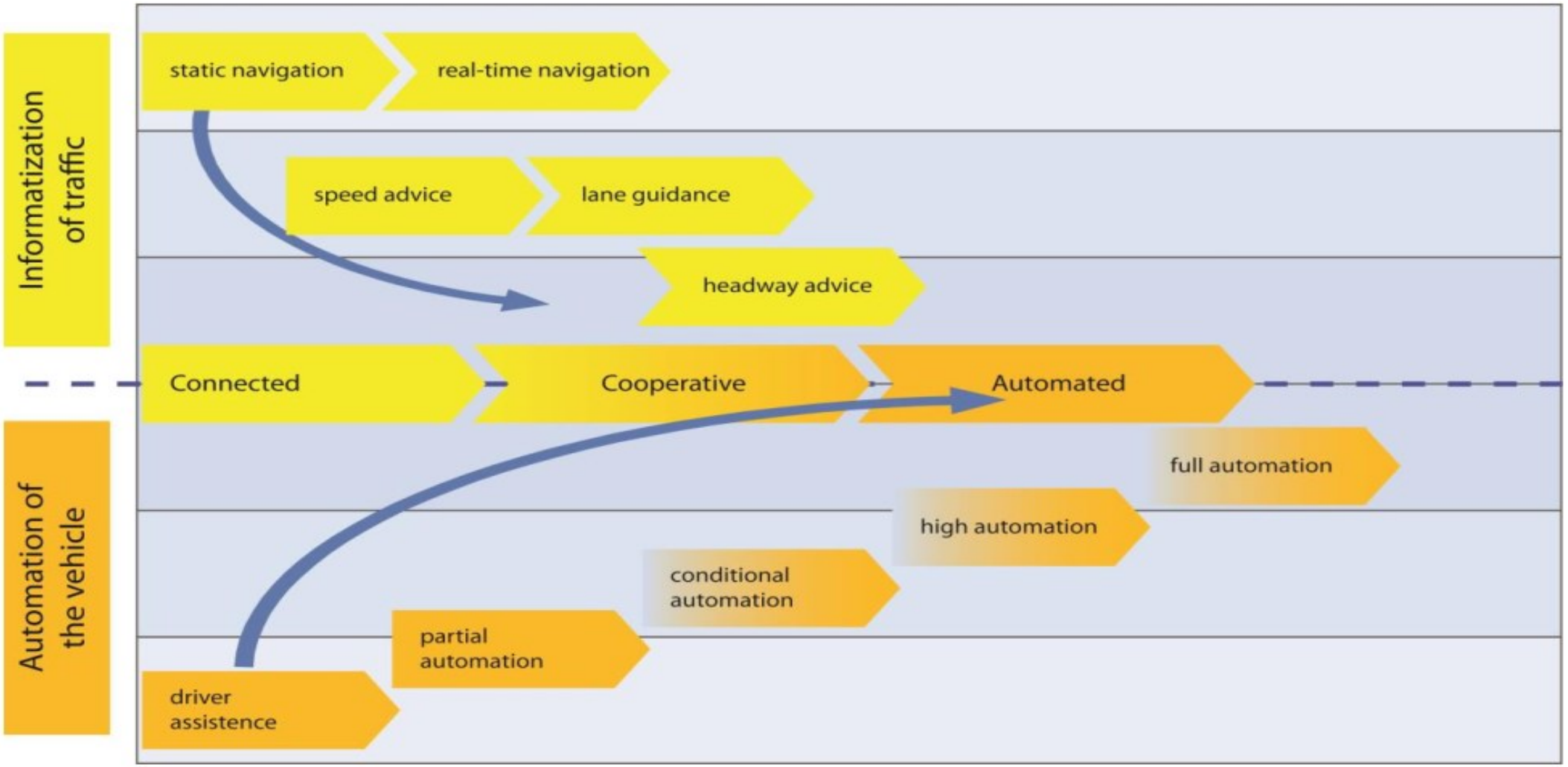
# Declaration of Amsterdam




*Connected, cooperative and automated driving developments should come together to harvest societal benefits.*

# Levels of Self-Driving Vehicles (Autonomous Cars)

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

Full Automation

Level 0

| 0 |
| --- |
| **No Automation**<br>Zero autonomy; the driver performs all driving tasks. |

# Levels of Self-Driving Vehicles (Autonomous Cars)

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

Full Automation

Level 1

| 0 | 1 |
|---|---|
| **No Automation** | **Driver Assistance** |
| Zero autonomy; the driver performs all driving tasks. | Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design. |

# Levels of Self-Driving Vehicles (Autonomous Cars)

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

Full Automation

Level 2

| 0 | 1 | 2 |
|---|---|---|
| **No Automation** | **Driver Assistance** | **Partial Automation** |
| Zero autonomy; the driver performs all driving tasks. | Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design. | Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times. |

# Levels of Self-Driving Vehicles (Autonomous Cars)

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

Full Automation

Level 3

| 0 | 1 | 2 | 3 |
|---|---|---|---|
| **No Automation** | **Driver Assistance** | **Partial Automation** | **Conditional Automation** |
| Zero autonomy; the driver performs all driving tasks. | Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design. | Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times. | Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice. |

# Levels of Self-Driving Vehicles (Autonomous Cars)

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

Full Automation

Level 4

| 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **No Automation** | **Driver Assistance** | **Partial Automation** | **Conditional Automation** | **High Automation** |
| Zero autonomy; the driver performs all driving tasks. | Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design. | Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times. | Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice. | The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle. |

# Levels of Self-Driving Vehicles (Autonomous Cars)

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

Full Automation

Level 5

| 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **No Automation** | **Driver Assistance** | **Partial Automation** | **Conditional Automation** | **High Automation** | **Full Automation** |
| Zero autonomy; the driver performs all driving tasks. | Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design. | Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times. | Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice. | The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle. | The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle. |

# Levels of Self-Driving Vehicles (Autonomous Cars)

Ultimately, there are three stages that will be relevant:

- automated
- autonomous
- driverless

# What a Driverless World Look Like?

Let’s think about driverless world a bit due to this entertaining presentation...

What a driverless world could look like _ Wanis Kabbaj.mp4

# V2X Overview

Vehicle to everything communication:

Connected and highly automated driving **can't be efficient** and **safe** without V2X!

- International innovation competition on standards and tools (winner takes the business)
- Promising benefits
  - Savings in energy and resource consumption
  - User experience for the traveller – automotives can sell more and/or more expensive cars
  - Safety and efficiency groves in mobility
- V2X Standardization
  - Messages have been defined in worldwide standards
  - Vehicles and infrastructure use the same standard

SWARCO V2X | Andreas.Schmid

# V2X: the Way of Communication

IEEE 802.11p

- is an approved amendment to the IEEE 802.11 standard
- adds wireless access in vehicular environments (WAVE),
- is a vehicular communication system.
- defines enhancements to 802.11 (the basis of products marketed as Wi-Fi)
- required to support Intelligent Transportation Systems (ITS) applications)

- Technology is ready
  - Initial „Day1“applications defined
  - 802.11p products for vehicles and infrastructure tested several times in laboratory and large field tests.
- Economic
  - Many applications are possible with one technology (often already cheaper than alternatives)
  - Tendency for price decreasing (global mass market)
- Development potential
  - Integration to cellular networks, further applications in research and development

SWARCO V2X | Andreas.Schmid

# V2X: the Way of Communication

Cellular

- LTE/4G
- NR/5G (in research and development)

- Technology of LTE/4G is ready
  - Usable as auxiliary communication way
  - latency ?
  - coverage limited
- Economic
  - Many applications are possible with one technology
  - Tendency for price decreasing (global mass market)
- Technology of NR/5G is under tests
  - Should be proper for every needs
  - low latency
  - no caverage yet, additional cellular towers necessary

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# Cooperative Intelligent Transport Systems (C-ITS)

- We combine information from many different areas and sources, such as:
- Road Infrastructure: such as traffic light controllers, urban central traffic control systems, and video and ANPR data
- Vehicles through V2X, e-bikes, public transportation fleets
- Other domains and external sources: such as 3rd party Floating Car Data (like on-line GPS based navigator applications)  and weather information

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# Cooperative Intelligent Transport Systems

- Real Time Traffic data is shared between vehicles, roadside infrastructure, traffic management centres, information services and even pedestrians.
- Information include Safety and Emergency data, followed by global connected services and finally cooperative management as a new information type.
- Traffic Management extends from physical to virtual space. Information and advices of this has same legal  requirement as physical signs.


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# Cooperative Intelligent Transport Systems

- Vehicle based data and phone based data are reliable data source.
- Investment in classic (strategic) detection is reduced – alternatives are cheaper.
- Infrastructure is protected against virtual attacks and is projected robustly into the virtual environment.
- ‘Cooperative’ functions are required in ‘classic’ products to stay in the market, including traffic control centers as well as road side controllers, detectors and signs.


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# Cooperative Systems – This is how future looks like:

- **Traffic lights** “see” vehicles. Single vehicles. Each position. Every second.
- Vehicles are distinguished by vehicle type (car, truck, bus, tram, emergency service). Where they come from and where they went to. Where they intend to go.
- Vehicles and traffic lights cooperate actively:
  - **Prioritisation** is distinctive. Public transport, emergency services, special executive safety transports, heavy trucks – all with the same technology.
  - Vehicles take into account **coordinated routes**, green waves and corridors.
  - Every intersection is sender & receiver of **safety warnings**


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# V2X Technology: aspects

Key aspects

I. Defined content – i.e. Standard messages
II. Defined applications - which are using the standard messages
III. Embedding in the existing environment

**I: Standard messages**

- „Basis vocabulary“ for the communication worldwide „Messages“ and their meaning
  - CAM
  - DENM
  - SPAT / MAP
  - IVI

  - …and what is always upcoming

# I: Defined content: Standard messages

**Standard Message Sets**

From “Cooperative Systems” / V2X a series of standardises messages are fixed,

- CAM (Cooperative Awareness Message defined by ETSI EN 302 637-2)
  - Most basic message, to every participant
  - The kind of a vehicle, position, speed, direction of a vehicle, Hz; optional content for prioritisation
  - When too much participant, the density of the transmissions will be automatically lowered
  - Later cyclists, and pedestrians may have participate (Question of chipset avalability)
- DENM (Decentralized Environmental Notification Message ETSI EN 302 637-3)
  - Warning messages to every participant
  - Accident, damaged car, kind of damage, congestion, traffic jam
  - Can be sent as well by traffic lights, traffic signs, VMS, RSU

CAM: Position, Direction, Speed, veh. Type, [other] @1..10Hz

DENM: Warning @event

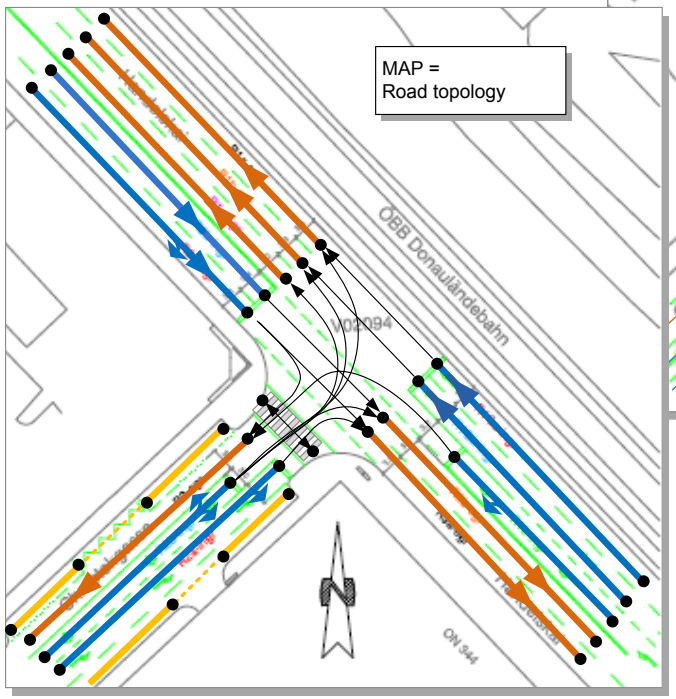
# I: Defined content: Standard messages

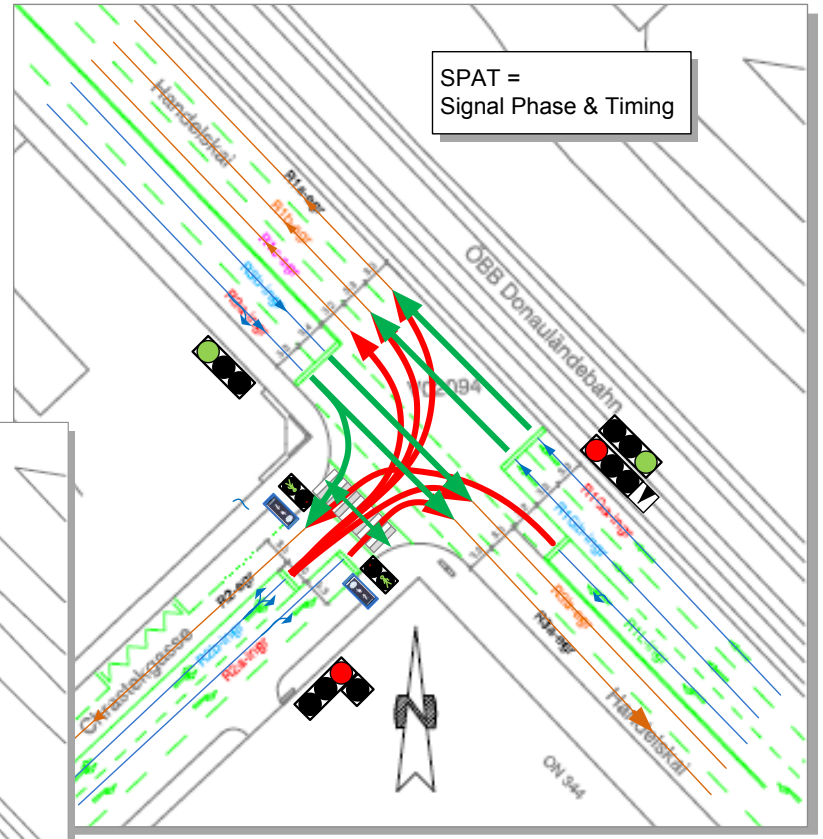
SPAT/MAP (SAE-J2735 und ISO 19091)

- SPaT: (Signal Phase and Timing)
  - Intersection traffic light status [and forecast] per signal group (=driving relation signaled identically)

MAP (Map topology)

- Is depicting each driving lane with at least two coordinates
  one being the stop- line
- Defines driving relations through intersection



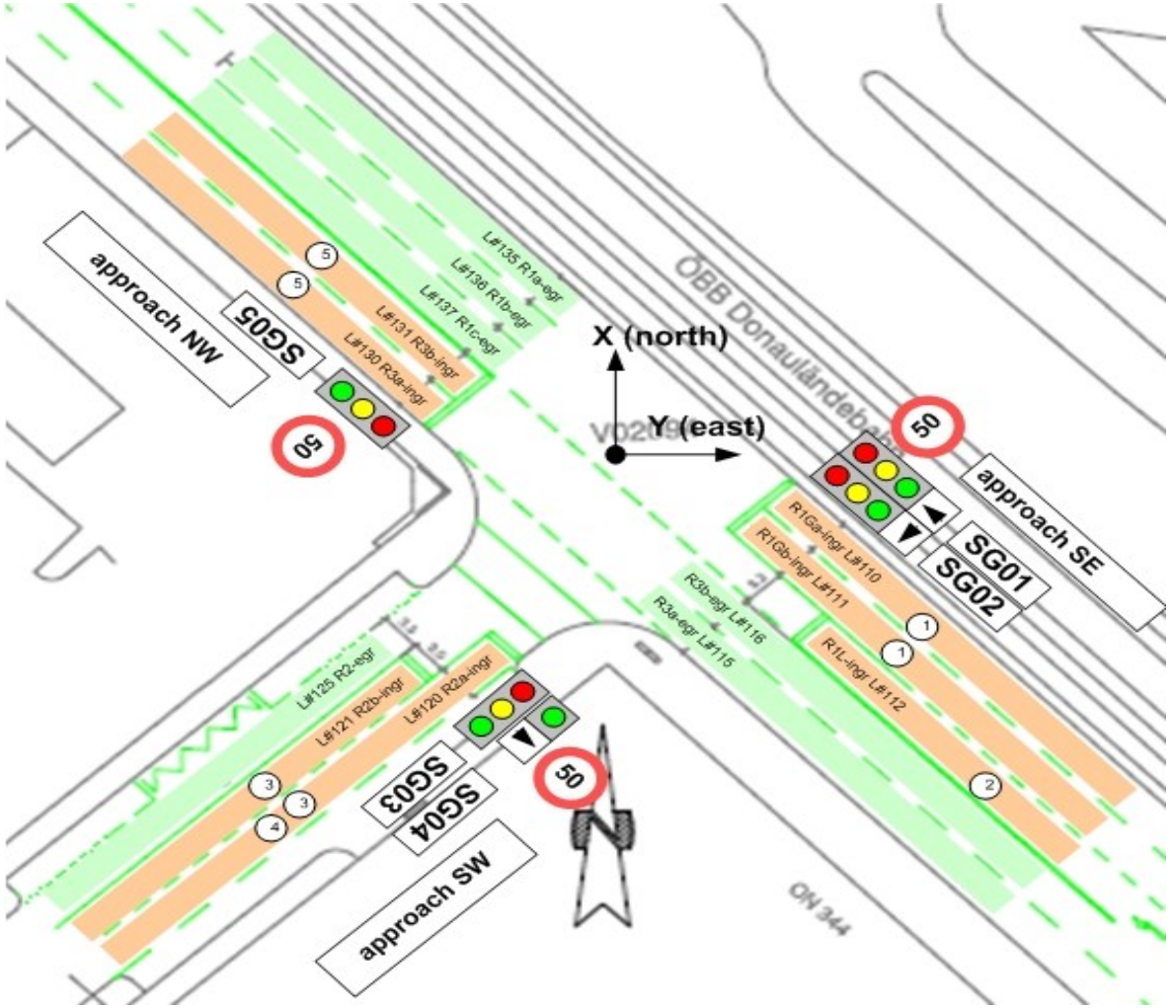



# MAP Message - Concept

- Topological definition of lanes  within an Intersection
- Links between the segments
- Related Signal-groups

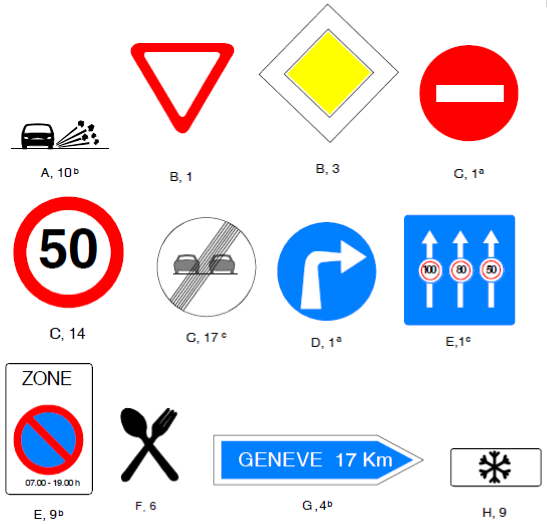
- Topological definition of lanes for a road-segment

- User restrictions, Speed restriction

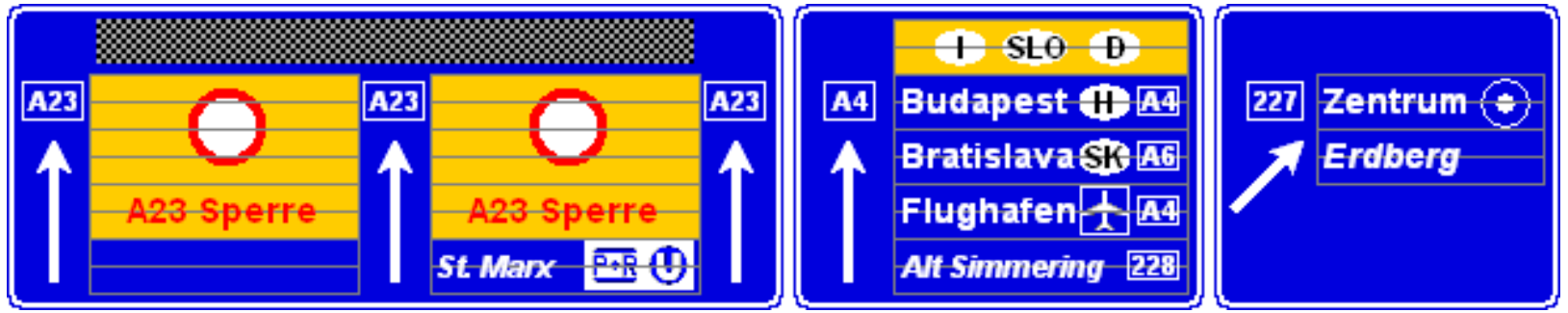


# I: Defined content: Standard messages

- IVI (In Vehicle Information (ISO/TS 19321)
- Content of [dynamic] road signs






Images: ECo-AT ECo-AT_SWP2.1_InVehicleInformation

# II: „Standard“ applications

- Applications – or:
  … this is what you “talk about” using the “basis vocabulary"

  - Construction site warning with signalizing trailers: Roadworks Warning
  - How to „catch“ the green signal / how long to wait at red: GLOSA/TTG
  - Red-light violation: Recognize, warn, react in vehicle
  - Prioritization: secure and differentiated priority with economic V2X standard technology
  - Dynamic road signs: this is how automated driving functions recognise them safely
  - „Ghost“ traffic jams: Damping of shock waves.
  - Accurate collection of statistics of traffic through the intersection.

  - ……and whatever is upcoming

# II: Defined applications

How are we using them?

- Roadworks Warning (RWW)
  - Allow vehicles to “see” warning trailers
- General (safety) warnings
  - Mark upcoming area to be driven with care
  - Local hazards
  - Share information on slippery road, jams ends, accidents,…

Image: drive-c2x.eu

Cooperative Warning

- Is precise ‘on the spot’
- Injects “electronic knowledge” on risks to our safety systems

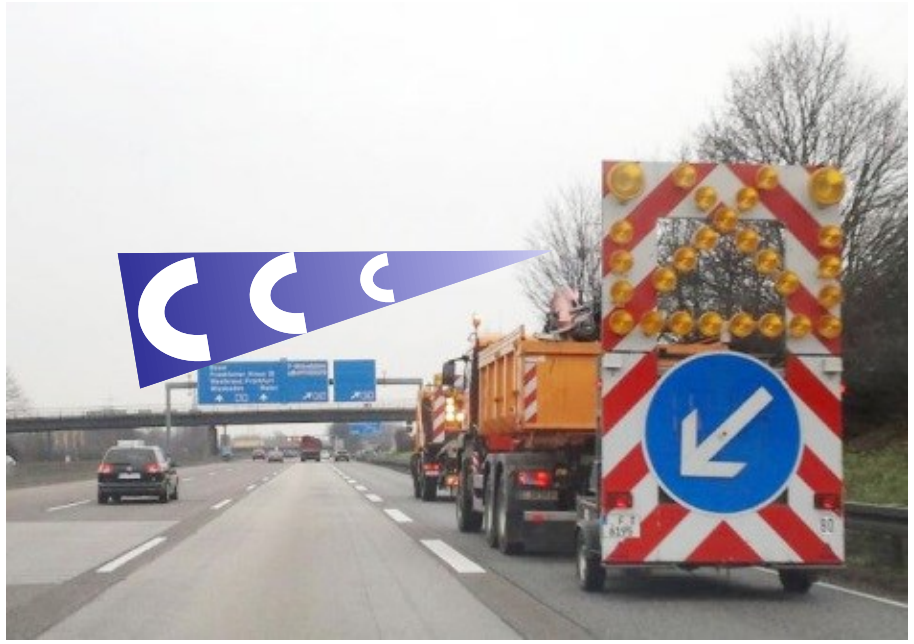


Image: https://www.afas-online.de/

# II: Defined applications

- Greenlight Optimal Speed Advisory (**GLOSA**)
  - Show the driver at which speed the next intersection can be passed
  - Drive without need to rush for green
- Time to green (**TTG**)
  - Show the driver when green is back
  - Take a relax at red / be prepared for green in time
- Start-stop engine ignites just before green
- drive-train / energy management and vehicle comfort functions
- ACC/ Gear-shift and all. energy functions adapt to traffic flow

(A premium driving experience! )

Cooperative Greenlight functions

- Save fuel & reduce pollution
- Bring comfort and “Wow” to drivers
- Increases throughput
- Enhance safety
  Relaxed drivers are a safety plus!

# II: Defined applications

- Intersection safety :
  Red-light violation recognition
- Vehicle / intersection can warn others
- Vehicle saf

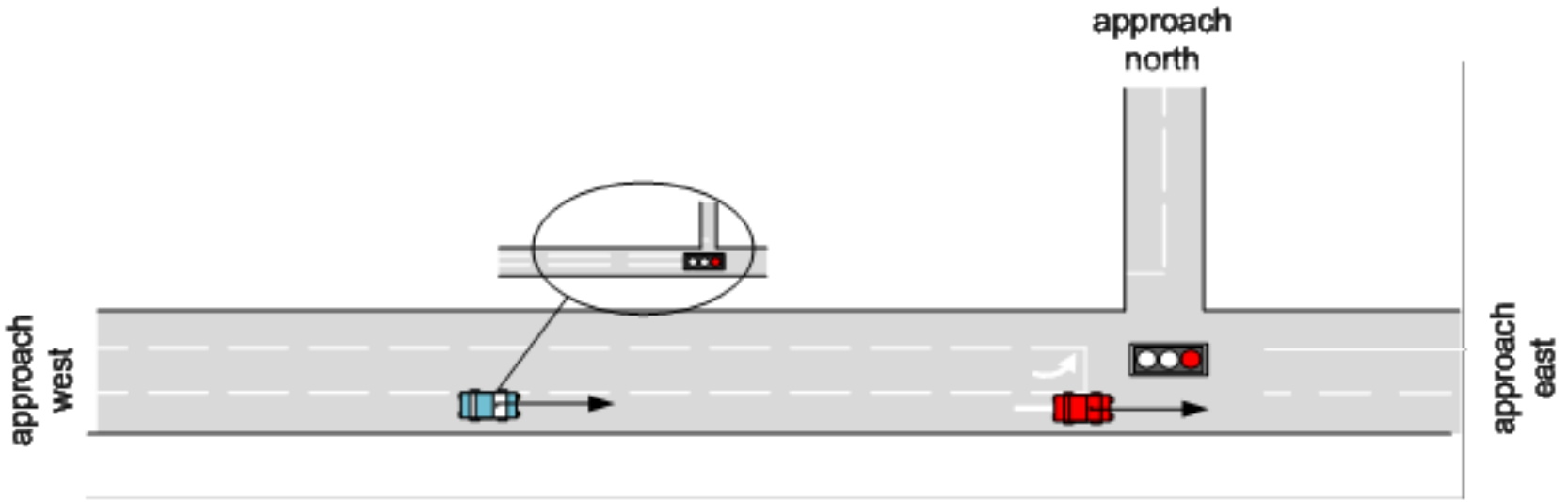



Image: ECo-AT SWP 2.1 Use Cases Intersection Safety

# II: Defined applications

- Prioritisation
  - Standard “CAM” messages are used to track continuously the approaching vehicle.
  - Allow different specific prioritisation
    E.g.:
    i) trams & buses,
    ii) police & emergency services,
    iii) heavy goods vehicles
  - Use V2X built-in security mechanisms to flexibly add & remove usage permissions;
    E.g. borrow buses from neighbour city for special event and use them in priority schema

- Cooperative Prioritisation
- Saves fuel & reduces pollution
- Saves cost
  (no further technology added / V2X technology can be used for several use-cases, vendor independent)
- Is based on mass (V2X) technology
- Is flexible
- Comes with state-of-the-art security

# II: Defined applications

- Variable signs: Speed limits

Image: drive-c2x.eu

- Shockwave damping
  - Avoid creation and propagation of jam ends due to oversaturated traffic flow
    - Already shown in A58, NL
    - To be deployed in C-ROADS, Hessen, Germany

**Shockwave Damping**


Image: trafficwaves.org

Today: congestion-wave in oversaturated traffic

Tomorrow: Speed recommendations between signs directly to the on-board assistance systems

C-ROADS

Hessen Mobil
Straßen- und Verkehrsmanagement

Launch Q4/2018: C-ROADS Hessen

HESSEN

Continental

# II: Defined applications

**Traffic statistics**
Use vehicle based data

Every second a probe:
V2X-CAM messages as source

- Probe data in intersections
  - Stops (per lane; before/after stop line)
  - waiting- and travel times
  - Origin- Destination (turn relations)

- One detector for several100m
  - Speed / travel time on various lanes or ramps simultaneously
  - Congestion / disappearing of a jam

Cooperative traffic data

- Allows traffic analysis in a new dimension, since it is based on precise single vehicle data

# III: Communication Technology

**ETSI ITS G5 aka “WiFi-P”**

5.9 GHz 802.11p based communication

- Availability
  - Commercial of the shelf (Cots) chipsets and units from various vendors on the market available
  - Tested in integrated scenarios with functions as mentioned prior
  - Integrated in Infrastructure “extensions” from many infrastructure vendors (Traffic Light controllers, Roadsigns, warning trailers)
- Features
  - Free to air (no provider / provider network required)
  - Low latency (sufficient for safety / highly automated functions)

Foto: Cohda Wireless

# III: Infrastructure - C-Roads

How to complete the existing environment with integrated V2X functions

This will be the starting point at next time...

Thank you for your attention!

Foto: Cohda Wireless