LECTURE

6

COOPERATIVE SYSTEMS (principles, applications)

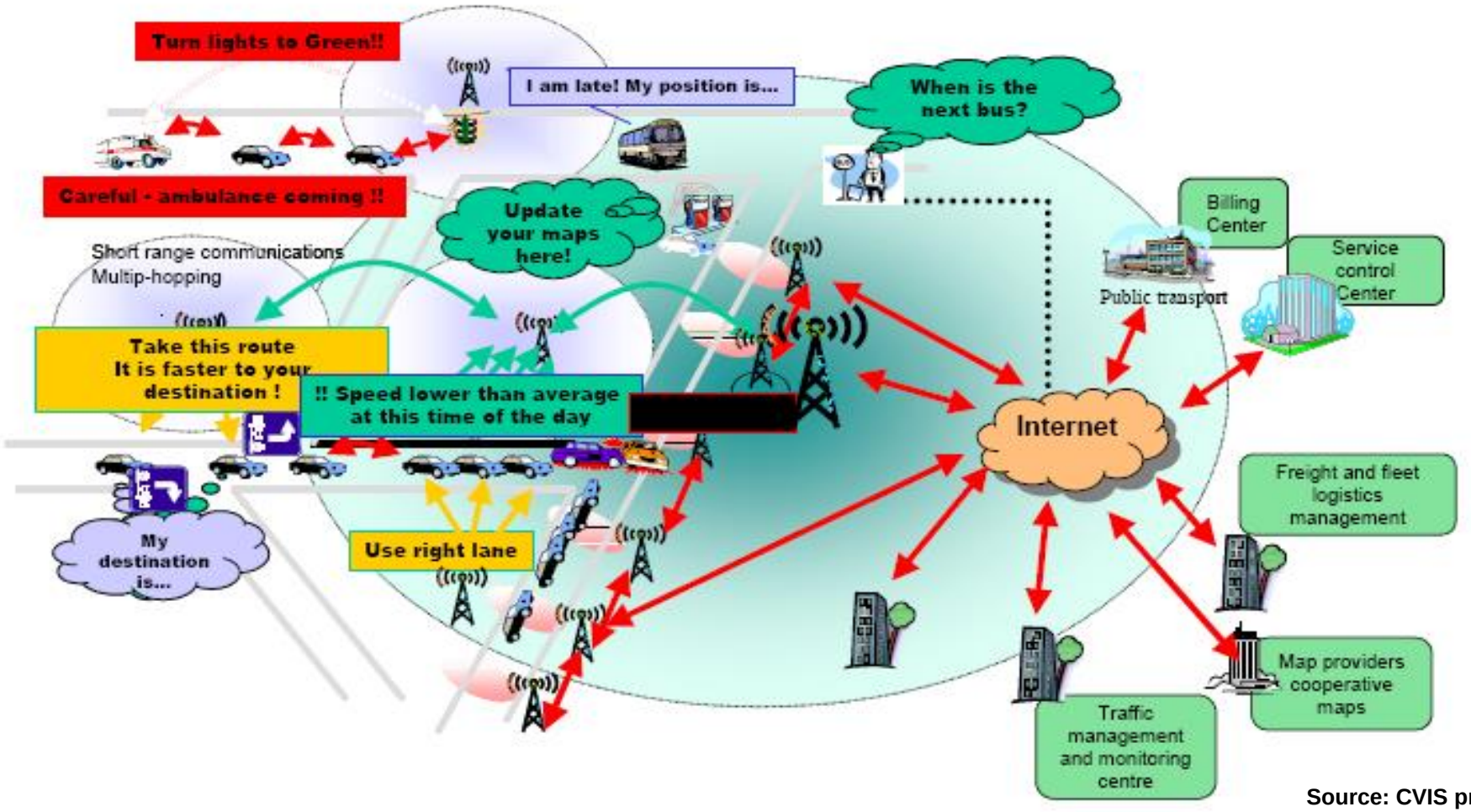
Lecture 6 - Overview

- Cooperative systems
  - Principles
  - Requirements
  - Deployment scenarios
  - Applications overview

Cooperative systems

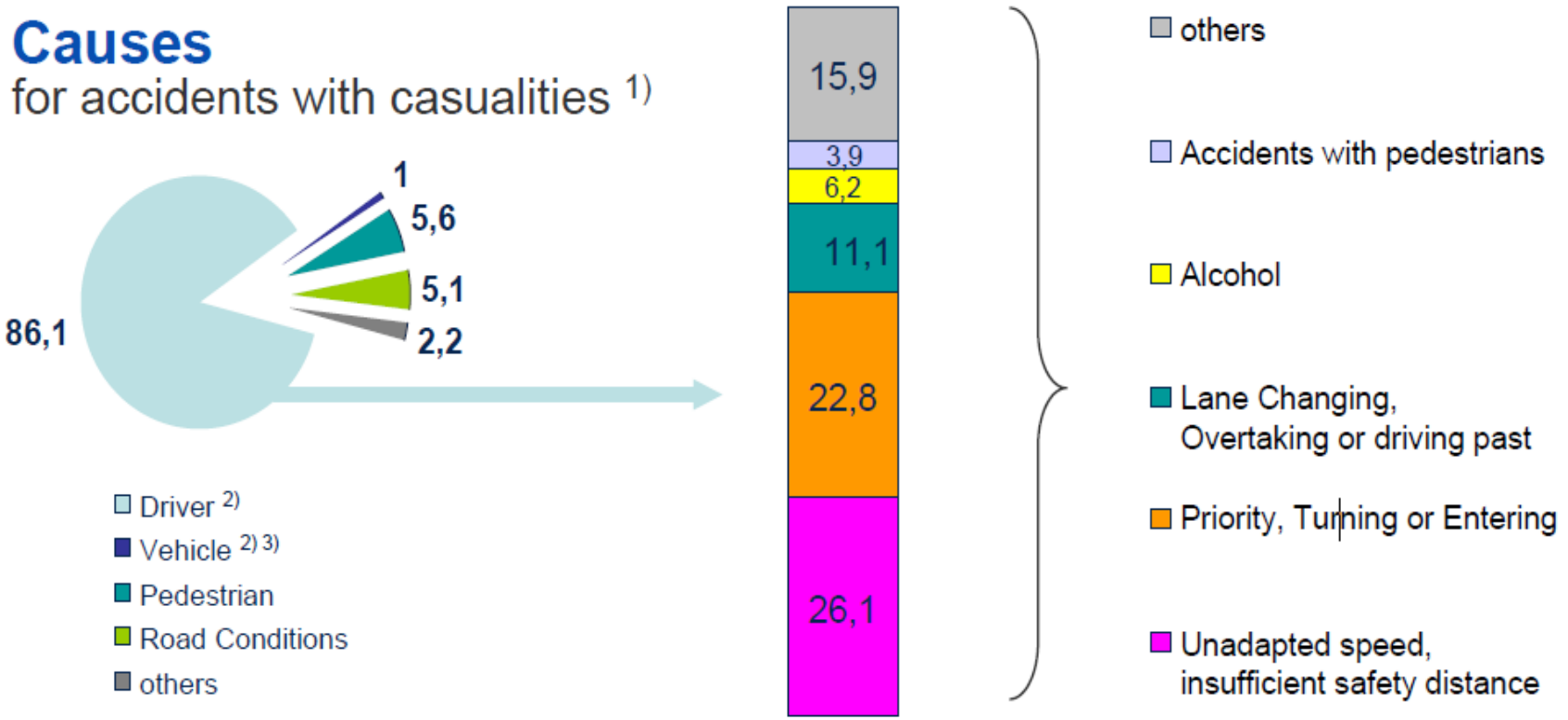
- Based on sharing information among traffic participants
- Modifying their behaviour in the light of knowledge of others' actions and intentions

Cooperative systems visions



Source: CVIS project

Cooperative systems - motivation



Source: Verkehr in Zahlen 2003, Deutscher Verkehrs-Verlag, Car2CarCommunicationConsortium
1) cause reported by police 2) vehicles, motorbikes, bicycles, others 3) technical faults

Germany, 2003

Cooperative systems - motivation

Sequence	Accident cause	Number of accidents
1.	Distracted driving	6.704
2.	Inappropriate vehicle speed	5.241
3.	Other cases of wrong drivning	3.094
4.	Not maintaining a safe following distance	2.848
5.	Wrong turning of backing-up	2.782
6.	Uncontrolled driving	1.888
7.	Not-adjusting the speed to the traffic-technical road state	1.712
8.	Running Stop Signs	1.653
9.	Wrong-way driving	1.091
10.	Avoidance manoeuvre without enough side-to-side spacing	1.074

Accident rate on road communications in the Czech Republic during 1. half-year 2013, www.policie.cz/soubor/2013-06-informace-pdf.aspx

Motivation of various subject to introduce new ITS applications

	Safety	Speed	Congestion avoiding	Profit	Easy maintaining	Emergency services	Assistance services	Law enforcement	Environment
Drivers	x	x	x			x	x		
Infrastruture mainteners				x	x	x			
Car manufacturers				x		x	x		
Legal authorities	x							x	x

Types of cooperative systems

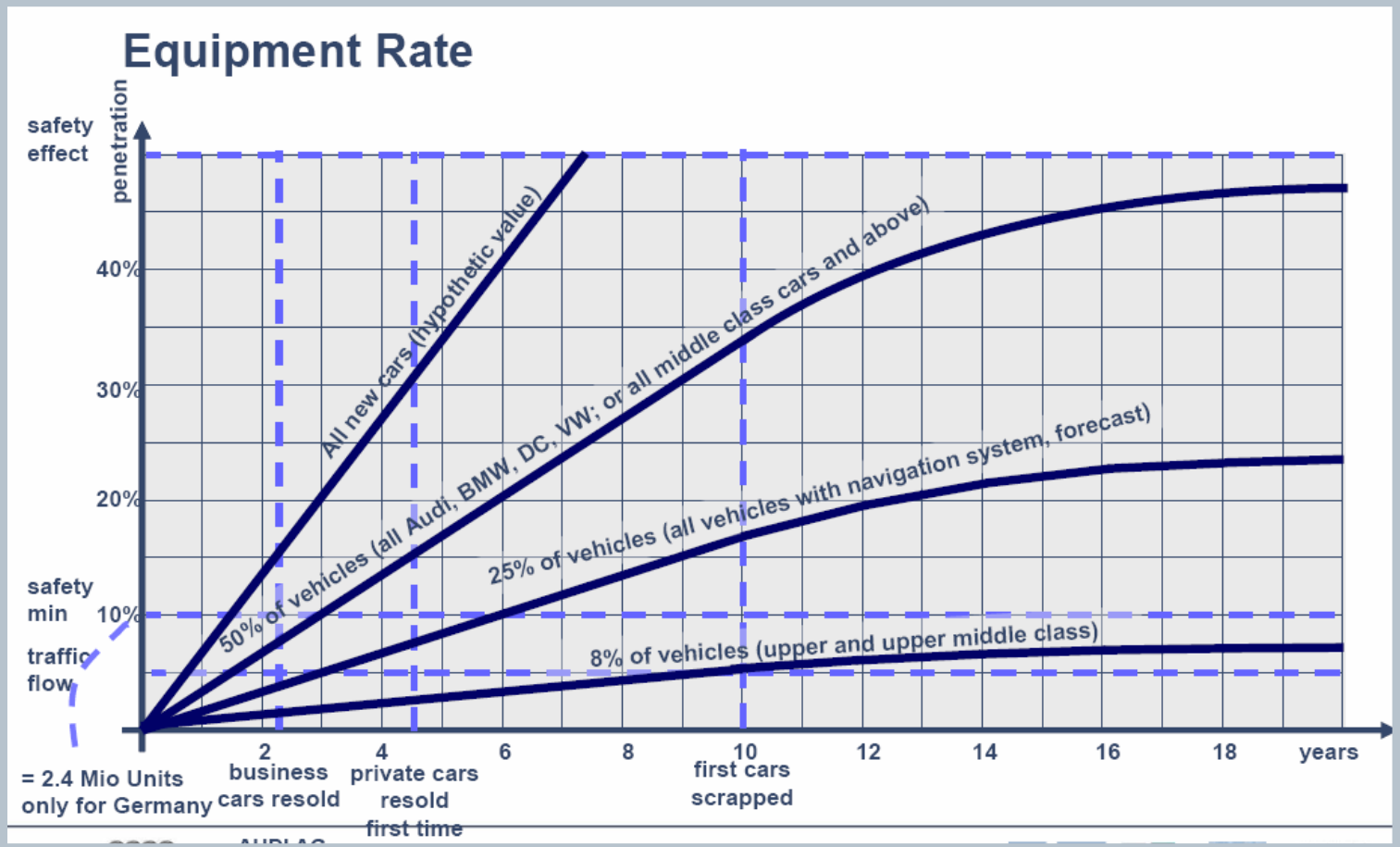
- Based on communication
  - Vehicle-to-vehicle (V2V) or Car-to-car (C2C)
  - Vehicle-to-infrastructure (V2I) or Car-to-infrastructure (C2I)
  - Vehicle-to-other participant

In general vehicle-to-X communication (V2X)

Requirements, deployment risks, etc.

- Functional:
  - system complexity/stability
  - missing consistency
- Economical:
  - business models
  - funding
- Technical:
  - technology
  - data availability, data ownership
  - information overflow
- Legal
  - protection of the system and its security
  - protection of privacy and of information
  - regulation of liabilities

Functional Example of equipment rate development



Menig C., Audi AG: Prezentace C2X kurz, Mnichov, 05/2009

Current situation

- So far useful business case is missing
- EU strongly supports cooperative systems development
  - Expected safety benefits
- There were several EU funded projects dealing with cooperative systems
- After their closure and demonstration of activities new projects launched aiming at the placing in operation

Cooperative systems business model

- How will they get paid, and by whom ?
- Cooperative Systems may require a number of stakeholders
- Consideration of these issues leads to the following questions:
  - Which are the most likely deployment scenario?
  - What role should be played by the road and highway operators?
  - How will investment and expenditure from public sources be justified?
  - Which practicalities have to be solved before the deployment can go ahead?

Deployment Scenarios

- **Industry Driven Scenario**
  - group of industry partners agree to support the introduction of Cooperative Systems
  - agrees on the common basic road safety-related functionality necessary for cooperation
  - Challenge – achieve the agreement
- **Regulation Driven Scenario**
  - Public authorities take the initiative to introduce Cooperative Systems – e.g. by European Directive
  - Basic road safety-related functionality is defined and standardised.
  - introduction is made mandatory for new equipment purchased from a certain point in time
  - Challenges – achieving agreements between the Member States

Deployment Scenarios

- **Common European Mobility Scenario**
  - Public authorities and industry agree on the introduction of Cooperative Systems
  - Development will be done with a special focus on inter-operability
  - Challenges - reaching an agreement on the roles and responsibilities
- **Market Driven Scenario**
  - Big industry players indroduce their own Cooperative Systems solutions independently on the others
  - Specialization on the customers of particular subject
  - In time market will consolidate
  - Challenges – achive interoperability, high cost for development „not winning“ technologies, risk of loosing customers having high expectations

Legal issues: Political support

- ITS Action Plan
  - On 16 December 2008, adopted by the European Commission
  - Suggests a number of targeted measures and a proposal for a Directive laying down the framework for their implementation
  - Goal is to create the momentum necessary to speed up market penetration of rather mature ITS applications and services in Europe.
  - The initiative is supported by **five co-operating Directorates-General:**

    DG Energy and Transport (lead), DG Information Society and Media, DG Research, DG Enterprise and Industry and DG Environment.
  - **23 April 2009, European Parliament approval**

Legal issues: Communication standards

- EC Standardisation Mandate M/453
  - Issued by the European Commission in late 2009 to the three main European SDO's, CEN, CENELEC and ETSI
  - To produce plan to cooperate in the development of a set of standards regarding V2X communication
  - ETSI and CEN produced „Response to Mandate M/453“, CENELEC is not taking part
  - This response contains aspects to be standardized

Cooperative systems benefits assessment

- Effect of cooperative systems depends on traffic situation, communication situation
- Modelling must include both parts – traffic and communication
- Also important – mutual influence – reaction to the received messages
- Recently cooperative simulation environments were added into the traffic modelling software
- Another possibility – use specialized software for each of the parts, e.g.
  - Traffic modelling e.g. Aimsun, Vissim
  - Communication modelling e.g. NS2

Data sources for the cooperative systems

From internal vehicle sensors	Brakes	Active - inactive
	Velocity	in km/h
	ESP	activation
	Wipers	Switched off, switched on, intenzsity
	Outer termperature	In degrees Celsius
	Time	GMT time
	GPS	Position, heading
Sensors for measurement of other vehicles' distance and speed	Lane position	Number of vehicles, their width, heading
	Proportion analysis of surrounding objects	Estimation of width, size proportion, etc.
Video system	Object detection	Relative position, speed and heading regarding to particular vehicle and traffic lane
	Vehicle movement estimation	Positon in the traffic lan, trajectory, etc. Used for worning against deflection from lane

Data sources for the cooperative systems

Monitoring of driver' state	Fatigue monitoring	High – middle – low
	Stress monitoring	High – middle – low
From infrastructure	Specific messages	Accident Congestion start Congestion end Weather – rain, hailstones, storm, wind, glaze, fog, …
Vehicle -to –vehicle communication	Specific messages	Obstacle in communication Weather Congestion Accident …
Traffic control system	Specific messages	Weather High traffic flow Dangerous place Communicaton maintenance...

Types of transmitted information

- Periodic messages („Beacons“)
  - Obtain local traffic information to detect dangerous traffic situations
  - One-hop broadcasts
  - Probability of reception
- Event-driven messages („Emergency message“)
  - Hazard detected, needs to be communicated
  - Information dissemination
  - Latency

Cooperative systems applications

Application types of cooperative systems

- Types of applications according the usage *(source: CVIS project)*
  - Traffic and Travel Management Applications
  - Logistics and Freight Management Applications
  - Safety applications
  - Maintenance applications

Traffic and Travel Management Applications examples

- Route planning and re-routing
- Provision of accurate input data for Traffic Management Centers
- In-vehicle display of dynamic traffic signs and speed advice
- Dynamic lane allocation
- Traffic prioritization
- Intermodal journey planning
- Dynamic tolling / congestion charging levels

Logistics and Freight Management Applications examples

- Parking zone management
- Truck access control
- Dangerous goods management
- Multi-modal freight transport planning

Safety applications examples

- Cooperative Manuevering
- Emergency Broadcast
- Safety Warning
- Pre-crash Mitigation
- Cooperative Sensing
- Coordinated Breaking

Maintenance applications examples

- Sensor Calibration (sensors function verification e.g. Using the cooperation of two sensor units)

- Remote Diagnostics (vehicle diagnostic data collection to the service centre)

Cooperative systems applications examples

Traffic and Travel Management Applications

Lane utilisation

- The lane utilisation application enables dynamic lane restrictions and permissions depending on location, time or vehicle type. Lane keeping is another message type designed to stabilise traffic flow and postpone or even prevent the accumulation of congestion. Together with lane specific positioning, lane specific advice can be given. For example, only those drivers in the lane to be blocked get the advice to change lane.

  This application also presents opportunities for road efficiency, e.g. dynamic hard shoulder use or flexible use of a bus lane.

Source: COOPERS project, CVIS project

Traffic and Travel Management Applications

Virtual VMS

- The Virtual VMS application enables the traffic management centre to provide drivers with routing or safety related information. One of the added values is that the application adjusts the language of the message to the drivers' preferences. Another advantage is that messages can be broadcasted by a road side unit, which reduces cost on VMS signs and increases the availability.
  The signs are sent to the car whenever appropriate, e.g. for the School children alert it is timebased – depending on the school opening and closing times.

Source: CVIS project

Traffic and Travel Management Applications

Road user charging

- The road user charging application implements kilometre based tolling according to the Dutch government proposal for truck tolling. It is based on a distance calculation with congestion zones (cities) and congestion corridors (road segments) with increased tariffs. It also supports rush-hour tariffs and geo-fence based charging points (virtual gantries). This part of the public road tour shows the information and tariffs for this part of the ride, and how fares are calculated in-vehicle for privacy. Aggregated distance is communicated periodically utilising CALM and IPv6 to the EETS (European Electronic Toll Service) compatible tolling back office in direct contact with the in-vehicle application.

Source: CVIS project

Traffic and Travel Management Applications

Access control

- The vehicle receives an announcement when it approaches the controlled area of the city. Specific rules are downloaded relating to the actual local situation, e.g. a truck-free zone. When entering the sensitive area, the rules are applied and matched with the specific vehicle's information to allow or deny access. If no access is allowed navigation recommendations are provided that avoid the area and guarantee smooth continuation of the journey.

Source: CVIS project

Traffic and Travel Management Applications

Priority application

- Priority is requested for a vehicle approaching a traffic signal. In case no immediate priority is possible speed advice can be given so that the vehicle creates its own green wave. In practice this priority application can be used for public transport and heavy transport. Preventing heavy vehicles braking reduces CO2 emissions greatly.

Source: CVIS project

Traffic and Travel Management Applications

Speed profile

- The application provides speed advice to the driver based on current and future traffic signal stages. This application uses short range (CALM/ WAVE) communications to exchange information between the traffic controller and vehicles. The traffic control strategy is communicated to the vehicle in order to give it a ‘green window’. If the vehicle is stopped at a traffic light, the ‘time to green’ is shown on the control panel display.

Source: CVIS project

Traffic and Travel Management Applications

Micro routing

- Equipped vehicles receive routing advice based on traffic light plans, the network, congestion, incidents or environmental constraints. The driver receives both the estimated best route to his destination, as well as a predicted trip time for the best alternative. The main innovative aspect of this application is the use of detailed traffic signal plans rather than average traffic flows to predict travel time.

Source: CVIS project

Logistics and Freight Management Applications

Parking booking

- This application arranges a reservation a parking space. In this application, the vehicle can make a reservation either automatically or when prompted. A central booking system processes the reservation and informs the vehicle of the parking location, and time slot. If needed, due to e.g. traffic delays, an updated time or location will be suggested by the system.

Source: CVIS project

Safety applications

Wrong way driver alert

- The vehicle receives a safety warning from another equipped car (driving the wrong way on a road) which sends warnings to all vehicles in the vicinity. The traffic control centre is also informed. The control centre can immediately inform approaching vehicles on the route for the hazard in advance before they actually encounter the vehicle coming in their direction.
- Or the presence of the wrong-way vehicle is detected by the wireless sensor network installed on the roadside barrier. Data signals are sent to the roadside unit where the SW application identifies the danger and immediately generates a set of warnings: a radio message is sent to all equipped cars in the vicinity, prompting a warning display on the control panel, while a VMS panel tells all approaching drivers that the exit is temporarily closed. At the same time, red warning lights on the slip road are activated to advise the wrong way driver to stop.

Source: CVIS project, COOPERS project

Safety applications

Prevention of accidents involving vulnerable road users

- An equipped vehicle receives a safety warning for a possible collision with vulnerable road users when turning right at an intersection. Accidents with pedestrians or bikers, which often lead to severe injuries, can be prevented with this application.

Source: SAFESPOT project

Safety applications

Accident warning

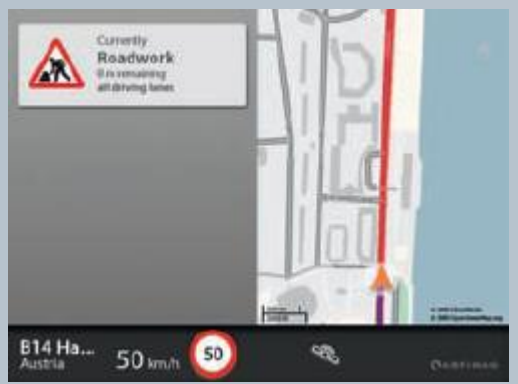
- This application demonstrates the accident warning which is a key service for improving safety on motorways. The driver is warned in advance of a hazardous event to raise his/her awareness and give time for early preparation. The message indicates start and duration of the event as well as its cause. Messages are displayed according to priority, distance, nature of the event and only if they are of direct interest for the driver.

Source: COOPERS project

Safety applications

Roadworks warning

- Roadwork information is triggered directly by the roadworks management system. Therefore warnings can be received in advance or directly at the beginning of road works. Maintenance units report their location and status back to the management centre which enables provision of updates to the driver.

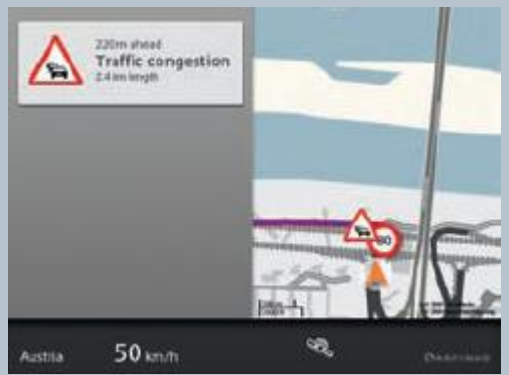


Source: COOPERS project

Safety applications

Congestion warning

- In general the system displays the traffic congestion warning on the left side of the display. The message contains the nature of the congestion, when it starts (e.g. 220m ahead) and how far it extends (e.g. 2.4 km to go). Additional information can be shown. The congestion is also marked in colour on the right side of the display.



Source: COOPERS project

Safety applications

Red light violator

- An equipped vehicle receives a safety warning when crossing a virtual stop line, while the traffic light is red. The detection of red light violators is useful for the violator that is made aware of the fact that he/she actually passed a red light. Secondly, this warning can be forwarded to other cooperative vehicles on the intersection. In this way all drivers are warned of potential dangers.

Source: SAFESPOT project

Safety applications

Intelligent cooperative intersection safety

- The Intelligent Cooperative Intersection Safety is a roadside system based on vehicle-to-infrastructure communication. The system determines the exact position of all road users and predicts their trajectories. In case of possible violation or a hazardous situation, the system sends out a safety warning. When approaching the stop line of a red light a safety warning informs us about the red light ahead and urges the driver to stop. As the vehicle stops in time, red light violation is prevented. Or a safe right turning in the presence of vulnerable road users is ensured - in this case a bicycle, detected by a laser scanner sensor installed in the road infrastructure.

Source: COOPERS project

Safety applications

Safety distance warning

- The Safety Distance Warning application gives a warning to the driver of a car that is approaching too closely to the vehicle in front. Using vehicle-to-vehicle communication and exchange of position and speed information, the vehicle behind computes the safe following distance with respect to the other vehicle. Should this vehicle approach closer than the safety distance, the driver of the following vehicle receives a warning that becomes stronger as the vehicles become closer and closer.

Source: COOPERS project

Safety applications

Collision warning

- The cooperative approach is used to prevent the potential dangerous situation, by means of a suitable warning advice.
- When the driver of the car decelerates and refrains from overtaking, the warnings will disappear from the vehicle display.
- The level of warning will also depend on the distance and relative speed between the car and the other vehicle.

Source: COOPERS project

Safety applications

Slippery road detection and warning

- The Slippery Road application produces a hazard warning when a “probe” vehicle travels into a part of the track which is slippery. The probe vehicle is able to detect this condition and warn the following-incoming vehicle. The following warnings are produced by the Slippery Road Detection and Warning application:
  - A message (Slippery Road icon) sent via the VANET from the detecting vehicle to the following/incoming vehicle, where this information is displayed on the vehicle HMI. The accelerator pedal of the vehicle is pushed back.
  - A message, displayed on a Variable Message Sign panel on the roadside, which warns (any) vehicle travelling on the main carriage way that the next road passage is slippery.

Source: COOPERS project

Safety applications

Safety margin for assistance and emergency vehicles

- In this application an assistance vehicle warns drivers through Variable Message Signs and through the Vehicular Ad Hoc Network), contributing to the improved safety of incoming vehicles, of road operators and of any other users involved in an incident. This application offers a prompt and pervasive service: road operators can quickly manage dynamic road changes, hazards and other events in short time and decide what to signal through a dedicated User Interface on their assistance vehicle. In this *Mobile Roadside Unit* concept, the infrastructure-based system can be deployed even in places where static roadside elements cannot be installed.

Source: COOPERS project

Other applications

Carpool matcher

- Within the CVIS project, the applications team organised an open contest for designing new applications. The carpool matcher shows how to diminish traffic and the corresponding jams through ride sharing. The application suggests inviting passengers to join the same car, when potential passengers for the same destination are cooperatively detected. In addition to reducing traffic, this application saves fuel consumption and instantly creates opportunities to meet new people!

Source: CVIS project

Telecommunication technologies of cooperative systems (summary from previous lectures)

Telecommunication technologies for V2X applications

Telecommunication solutions	Car-to-car	Car-to-infrastructure	Car-to-enterprise	Car-to-home	Car-to-personal equipment
Wi-Fi IEEE 802.11 e/n/p	X	X	X	X	X
DSRC 5,8 GHz / 5,9 GHz	X	X			
Mobile GSM network		X			
Mobile data networksEDGE, UMTS, HSPA, LTE, LTE-A	X	X	X	X	X
WiMax IEEE 802.16 e/m			X	X	
Bluetooth IEEE 802.15.1					X
MBWA	X	X	X	X	

Telecommunication technologies designed for the mobile usage in ITS

- WiFi 802.11p (WAVE Wireless Access for the Vehicular Environment) – support of mobile users in ITS
- WiMax 802.16e for mobile usage
- 802.20 MBWA (Mobile Broadband Wireless Access) for quick data transmission to mobile users (up to speed 320 km/h)

Requirements on the telecommunication technologies

Cooperative systems category	Application	Preffered telecommunication technology specification
Accident – high speed	1. Emergency electronic brake lights 2. Collision worning 3. Blind spot / Lane change warning 4. Overtaking warning 5. Left-turn assistent	Low transmission error rate High reliability Short delay (max. 100ms) High vehicle speed (130km/h) Minimal radio noise Robust with obstacles in the comunication way Middle range (max. 100m)
Accident – low speed	1. Cooperative intersection safety assistent	Low transmission error rate High reliability Short delay (max. 100ms) Middle vehicle speed(100km/h) Minimal radio noise Robust with obstacles in the comunication way Short range (10 – 100m)

Requirements on the telecommunication technologies

Cooperative systems category	Application	Preffered telecommunication technology specification
Eco-Green-Mobility / Vehicle speed	1. Electronic payments 2. Traffic data collection 3. Eco-line (Eco-speed) 4. Green wave 5. Traffic signals timing	Low transmission error rate High reliability High vehicle speed (130km/h) Minimal radio noise Robust with obstacles in the comunication way
Eco-Green-Mobility in general	1. Traffic signals timing	Low vehicle speed(30km/h) Minimal radio noise Robust with obstacles in the comunication way Short range(max. 50m)
Comfort	1. Guide to charging stations/information (pro EV) 2. Mobile marketing / advertisement 3. Internet access 4. Video/audio files download 5. Videocalls	High vehicle speed (130km/h) High transmission rate Stability Safety Privacy

Requirements on the telecommunication technologies

Cooperative systems category	Application	Preffered telecommunication technology specification
Safety informing	1. Remote diagnostic 2. Accident (standing vehicle) warning 3. Road status warning	High reliability Middle delay (0,5 – 1s) High vehicle speed (130km/h) Minimal radio noise Robust with obstacles in the comunication way Long range(100 - 1000m)
Emergency	1. eCall	Low transmission error rate High reliability High vehicle speed (130km/h) Minimal radio noise Robust with obstacles in the comunication way Long range(100 - 1000m)

Source: Lokaj Zdeněk. Habilitation Thesis

Cooperative systems applications summary

Cooperative system applications details

- There is no widely applicable policy for cooperative applications
- The cooperative applications‘ details are part of the companies‘ know-how and not public
- There are many issues to solve for each application, e.g.:
  - Message content
  - Message transmission
  - Message presentation
  - Etc.

Issues to solve in the design of cooperative system applications

- Content of the message
  - The event
  - Time, time of message generation
  - Position
  - Source, position of the source
  - Importance
  - Etc.
- Source
  - In vehicle
  - From external sensors
  - From the infrastructure
  - ...
- Transmission
  - Technology used
  - Protocol
  - Range
  - Etc.

Issues to solve in the design of cooperative system applications

- Message validity
  how to ensure the network is not overloaded by repeated messages
  - The validity may be based on
    - Time
    - Geographical location
    - Number of hops
    - Etc.
- Recognition of multiple messages
  - How to distinguish messages reporting the same situation from different source?
  - Based on event position, time, etc.

Issues to solve in the design of cooperative system applications

- Resending the message – should the vehicle receiving the message send it further on?
  - If yes, based on what parameters?
  - For what types of messages?
  - Depends also on the technology and its range
- If resend,
  - Should the message be adjusted
  - Updated
  - Possibility to change the importance parameter
  - Consolidation of the same messages received from different sources
  - Etc.

Issues to solve in the design of cooperative system applications

- Output - Informing the driver
  - When the driver should be informed – based on
    - Event type
    - Position of the event in relation to the route
    - Validity of the message
  - How the driver should be informed
    - Acoustic
    - Visual
    - Haptic
- Security
- And many others

Task: Cooperative applications design

Make your own proposal of following applications:

- Roadworks warning
- Special vehicle warning (e.g. emergency vehicle approaching, oversize vehicle warning, etc.)
- Congestion warning

Consider the following issues:

- Source
- Transmission (content, mode)
- Message validity (time, geographical location, number of hops)
- Resending the message
- Output – how to inform the driver
- Etc.

Thank you for your attention

D1 highway, Czech Republic, 20.3.2008

Source: MF Dnes