CAR 2 CAR
COMMUNICATION CONSORTIUM

# C-ITS: Europe's Path to Connected, Cooperative & Automated Mobility

www.car-2-car.org

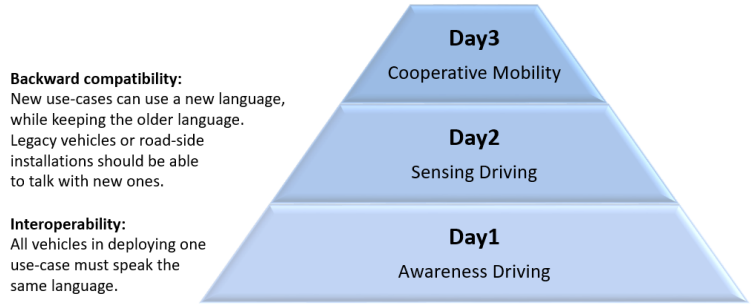
# Executive Summary

*Europe is leading in the deployment to vehicle-to-everything direct communication. In the EU's policy context this is referred to as 'cooperative intelligent transport systems', or C-ITS. Other regions or stakeholders may use other terms, such as V2X. C-ITS is essential to answer Green Deal objectives and reaching higher levels of safety by means of automation: It exchanges information that line-of-sight sensors cannot provide, it protects vehicle occupants, motor-cyclists and pedestrians and therefore will contribute to building confidence in automated mobility.*

*C-ITS is not built on a proprietary business model. It is an eco-system that is specified by those who operate it: Europe's automotive manufacturers and road operators. Automotive manufacturers organise themselves in the CAR 2 CAR Communication Consortium. Road operators come together in the C-ROADS platform. It is tailored to the joint mission of OEM and road operators to deliver safe mobility and create a framework for long-term public and private investment. It requires the cooperation of C-ITS 'deployers' and regulators. This cooperation is already working and has yielded what makes Europe unique: a common security framework and the close cooperation of the CAR 2 CAR Communication Consortium and C-ROADS.*

*C-ITS use-cases are evolving. New building blocks are built on top of legacy ones. The use-cases of tomorrow should be backward compatible with the vehicles of today. Interoperability assures that vehicles can implement a use-case without excluding other vehicles. Backwards compatibility ensures that consumers can enjoy the safety benefits of C-ITS during the lifetime of their vehicles. Furthermore the communication has to be trustworthy all the time.*

C-ITS progress: building blocks




*The EU bases its C-ITS policy approach on:*

- *Council's 'Declaration of Amsterdam on cooperation in the field of connected and automated driving'*
- *The European Commission's 'European strategy on Cooperative Intelligent Transport Systems'*
- *The European Parliament's report 'on a European strategy on Cooperative Intelligent Transport Systems'*

*European automotive manufacturers and road operators are filling these documents with life.*

*C-ITS is deployed. More than **500.000 commercially available vehicles are C-ITS equipped.** So are **20.000 km of roads in Europe**. Both figures are steadily rising. **The EU-wide common security framework is in operation.** This document describes how Europe can consolidate that lead.*

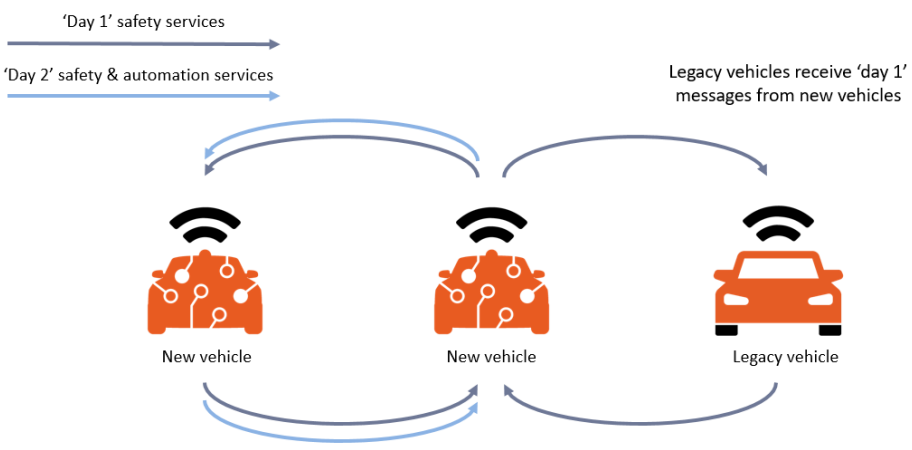



*Illustration: Backwards compatibility*

*C-ITS is driven by a cooperative approach to its use-cases. C-ITS actors are motivated by their public mission on which their individual business cases stand - road safety and traffic efficiency. To maintain this approach C-ITS has to be interoperable and backward compatible to protect investment and assure long-term value. C-ITS is as far as possible based on open and accessible standards and designed to keep licence costs at minimum. A technology has to be mature enough to guarantee the highest levels of road safety and open to an unobstructed technology evolution.*

*Adhering to these principles C-ITS services and applications are technology agnostic. Today, the ITS-G5 communication standard in Europe fully delivers 'day 1' use-cases. Regarding future technologies, industry welcomes the potential expansion of capabilities of direct communication, whilst maintaining the benefits of the C-ITS use-cases already deployed.*

## Continuity of use-cases for road safety is crucial

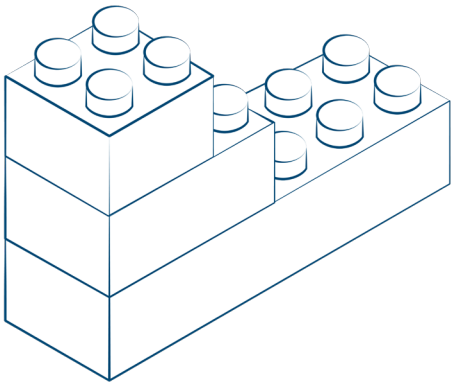
# The importance of technical interoperability and backward compatibility for C-ITS

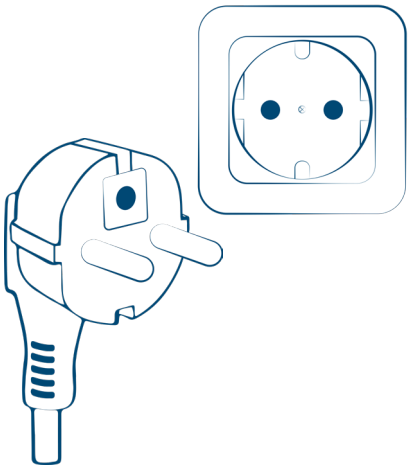
## The moment the system clicks!

**Technical interoperability**

These bricks 'click'. They are interoperable and all bricks that follow the specification on size and diameter of the studs will fit into the system. These bricks are technically interoperable.

C-ITS works just like that. The transmitters have to be built according to the same specification and they 'click', meaning they understand each other.





This plug fits into a certain specified socket. They are technically interoperable. They fit and electricity flows.

Metaphorically: C-ITS sender and receiver 'fit', information 'flows'.

This daisy chain makes electricity flow and could even be capable of transforming currents. Service delivery, the flow of electricity, requires a technical intervention to function.

For safety related C-ITS communication service level is too complicated and cannot be enough – safety communication has to be straight and resilient. Technical interoperability is safer and is needed in addition to service level interoperability.

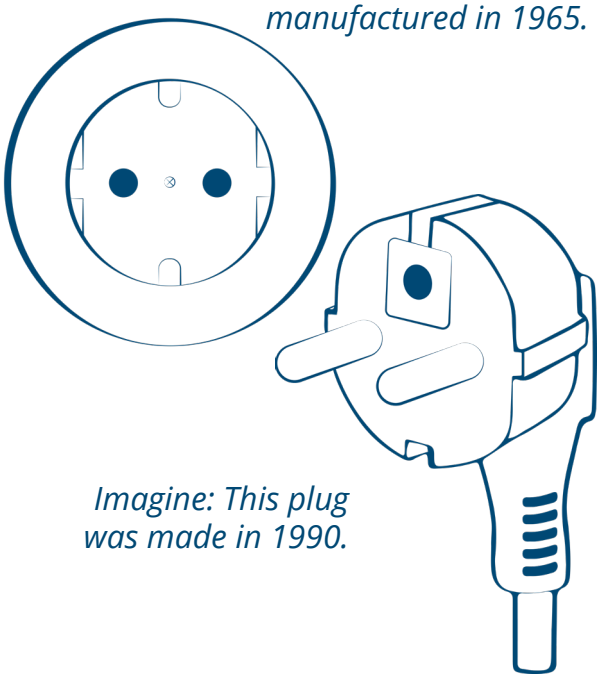
## Service level interoperability

## Backward compatibility

A plug produced 1990 works with a socket produced in 1965. The plug is backward compatible. A socket made 2022 is compatible with a plug made 1990. The socket is backward compatible. Backward compatibility is interoperability through time.

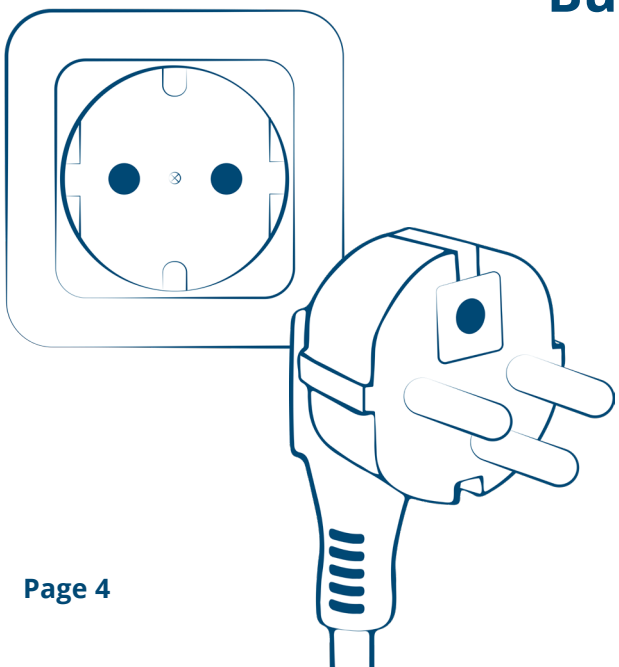
For the customer this means, you buy a piece of equipment in 1990, the plug works with a socket from 1965, as well as 2022. The plug is compatible through time. A win for the customer! This prolongs the usability of the equipment that connect with this plug.

*Imagine: This socket was manufactured in 1965.*



*Imagine: This plug was made in 1990.*

*This socket is made in 2022.*



**But imagine:**

What, if ...

*What would the introduction of a plug like this in 2022 mean?*

# Europe's Path to Connected Cooperative and Automated Mobility

Europe has set itself the goal to play a leading role in automated mobility. Cooperative communication is required. The resulting technical communication system is referred to as Cooperative Intelligent Transport System, or C-ITS.

Already now it is obvious that automation requires more than a vehicle equipped with a range of sensors. Sensors, such as radar, lidar or cameras, are limited to their line-of-sight and may not always understand what they see. They require additional information:

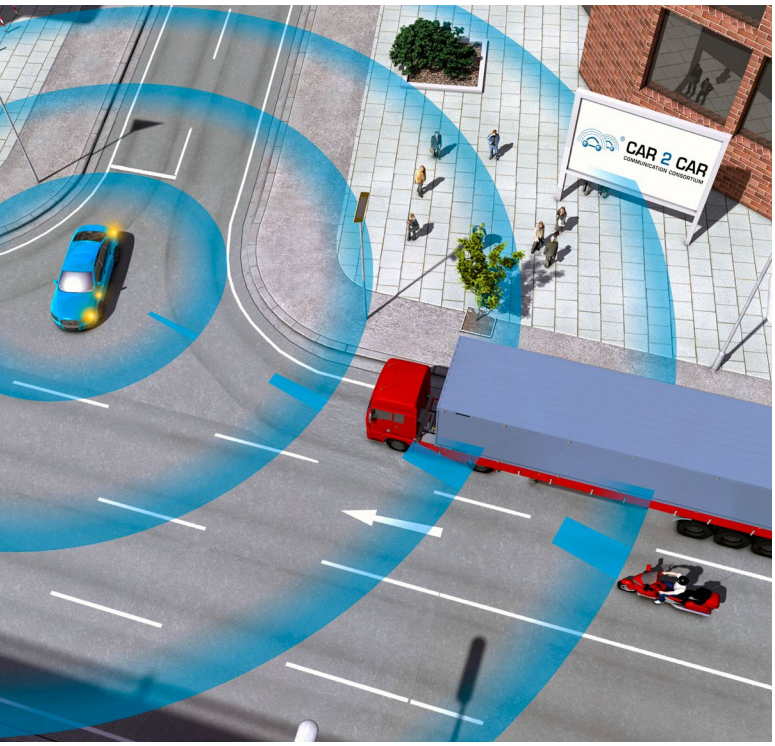
a.) To warn of what's happening out of the line-of-sight,

b.) To clarify what moves in the line-of-sight

c.) How relevant the information actually is

This may help an autonomous vehicle quickly solve the riddle whether that yellow disc the sensor sees is a traffic light or the sun; whether that line on the horizon is actually the horizon or the trailer of a crossing truck or if that traffic sign the sensor reads applies to the lane the vehicle is on.

Vehicles directly communicating to each-other is the 'cooperative' in connected, cooperative automated mobility. This 'cooperative' of course also covers road infrastructure. Though not as visible in the consumer's eye, it plays a significant role in this cooperation. Although autonomous driving seems far off, vehicles have a long life-span and the latest vehicles sold today will share the road with higher level automation vehicles in the future. This will not happen in a big bang, it's a gradual process with services building on each other and using the data they exchange. Long-term planning and continuity are key to achieving this goal.




*This paper outlines how Europe can achieve connected, cooperative and automated mobility. This requires a close cooperation between regulators, automotive manufacturers and road operators, data service providers and cellular mobile network operators on a governance level.*

# Cooperative-ITS

To make C-ITS work, automotive manufacturers and road operators have to work hand in hand to reach their shared public mission of increasing road safety and greening mobility. Towards this mission they have created the C-ITS eco-system that enables higher levels of automation, safer and more efficient road use. Sharing data for free using C-ITS is similar to listening to radio: your radio has to be interoperable with the sender, usually FM, AM or DAB, and you tune into a certain frequency for your favourite radio station. Like radio C-ITS requires functional and technical interoperability and radio spectrum to exchange data.

Automotive manufacturers and road operators specified the data exchange architecture and technical requirements that match the eco-system's exact needs. This whilst at the same time allowing for their business models and long-term investment cycles to function. They support each others' use-cases and aim at a common technology evolution on the path to road safety and automation, which is reflected in the concepts of interoperability and backward compatibility in the ITS Directive 2010/40/EC.

As common terminology the evolution of C-ITS is roughly grouped and described as 'days'. These 'days' describe clusters of use-cases with similar technical requirements, starting from 'day 1' services, upon which 'day 2' services shall be based, followed by 'day 3'. Important here is continuity to assure a development that covers the long product cycles of vehicles and road infrastructure.

## Policy Basics

*We are convinced that C-ITS creates a public infrastructure on which future automation relies, similar to the way the economy depends on transport infrastructure or IT infrastructure. Like the internet C-ITS is based on shared rules. C-ITS serves first and foremost the public good, most notably road safety and the efficient and sustainable use of roads. This credo we share with road operators and the EU. Here is what guides us:*

**Automation requires more than sensors on vehicles – vehicles must talk!** *So argues the US National Transportation Safety Board in an analysis of a crash involving an autonomous vehicle. We share this belief.*

**Automation improves road safety and efficiency.** *EU Member States agree so in the Amsterdam Declaration, the European Parliament makes it clear in its Report 'on a European strategy on Cooperative Intelligent Transport Systems (2017/2067(INI))', the European Commission states it in its 'European Strategy on C-ITS' and its 'Smart and Sustainable Mobility Strategy'. We aspire to translate these documents into reality together with Europe's road operators.*

**EU regulation supports a key building block to automation and road safety – C-ITS.** *EU spectrum regulation provides for sufficient radio spectrum and is open to new technologies, whilst assuring interference-free operation of existing radio systems. The current ITS Directive with its 'backward compatibility' and 'interoperability' requirements protects C-ITS from disruption, whilst offering an evolutionary path for innovation and improvements. The EU security framework for C-ITS makes Europe unique and is a keystone for future automation. We believe this is a solid foundation for long-term commitment from automotive OEM and EU Member States and we base our work on this regulatory framework.*

**EuroNCAP believes in C-ITS.** *EuroNCAP is an initiative by European transport ministries, automobile associations and insurance companies that benchmarks the safety standards of vehicles. EuroNCAP's '2025 Roadmap' shows an long-term commitment to C-ITS and raises expectations for the upcoming '2027 Roadmap'. The C-ITS 'day 1' application local hazard warning has already been recognised by EuroNCAP as advanced safety feature. It also shows the commitment of EuroNCAP's member transport ministries, automobile clubs and insurance companies to vehicle automation and their confidence in the C-ITS governance framework and the ITS-G5 short-range communication technology that C-ITS is currently ramping up with.*

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## ‘Day 1’ is now!
## Cooperative safety

***‘Day 1’ means your car knows what happens with other C-ITS equipped vehicles around the corner. You still do the driving yourself, you benefit from more time to react to the traffic situation.***

‘Day 1’ is now! Already today there are more than 500.000 vehicles in circulation using such services and 20.000 km of roads equipped in Europe.

‘Day 1’ are use-cases where vehicles disseminate information about themselves, such as speed, position, heading or if the vehicle detects immediate danger and to warn eachother. This is referred to as ‘cooperative awareness’. Since the trajectory of vehicles only concerns the direct environment of the vehicle itself and must be instant (no delays when we talk about road safety) vehicles use short-range communication: radio beacons that emit a radio signal directly around the vehicle, transmitting tiny data packets in that small area of communication. Less time critical and more data intensive transactions or transactions that require cloud data are performed using cellular networks. ‘Day 1’ use-cases cover a range of warning applications and the communication of infrastructure information, such as in-vehicle signage, traffic light signal phases and timing. Key here is that the services share a message format that automotive manufacturers and road operators agreed upon. Similarly the security of the communication is agreed by implementers and EU Member States. EuroNCAP has already recognised the ‘day 1’ use-case local hazard warning in its awards and with it: the ITS-G5 short-range communication technology.

Other radio services implement EU legislation along roads to make road transport safe and sustainable: 1.) the smart tachograph helps to control the rest times of truckers; 2.) weights & dimensions prevents truck overload; 3.) road charging to maintain roads and internalises the external costs of road transport, such as noise, air pollution and CO2 emissions. C-ITS has to be compatible with all of them.

1

**Eyes and Ears**

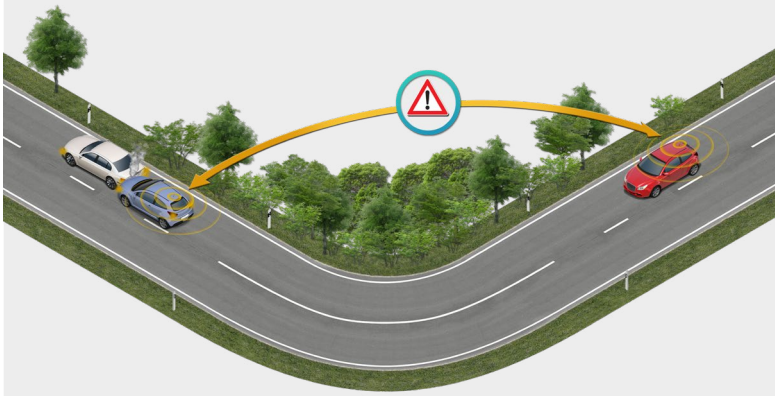
*In ‘day 1’ use-cases vehicles disseminate information about themselves and complement in-vehicle sensors beyond the line of sight. If vehicle sensors are the vehicle’s eyes that visually process the line-of-sight environment, C-ITS is the vehicle’s voice and ears, reaching where the eyes don’t see.*

*Corporate Awareness Message (CAM): This is a message, a tiny data packet, that a vehicle emits into its direct vicinity roughly every four metres to let other vehicles and the road infrastructure know what it is doing and where it heads to. These messages are forgotten, as soon as they are processed. The Corporate Awareness Message is transmitted via a radio beacon and can be received by any C-ITS station nearby. The advantage of the broadcast: it does not require any cloud or cellular network and it is faster than any other available form of communication, because it is direct and ad-hoc. The information it sends is only relevant right around the vehicle and only for a very short period of time.*

*Decentralised Environmental Notification Message (DENM): This message is event-triggered and warns of hazardous locations. It can hop from vehicle to vehicle and stays around a specific location.*

*Example - ‘Accident Warning’ - a ‘day 1’ use-case: this service bases itself on the broadcast and analysis of CAM to warn other vehicles of danger or generate DENM that warn vehicles of a risk.*

*Keep the CAM and DENM in mind, they will feature throughout ‘day 2’ and ‘day 3’.*



Example: Accident warning in curve

## ‘Day 2’ is coming!
## Cooperative extended perception

***You may delegate some more driving tasks to ‘day 2’ vehicles. Your car knows pretty much what’s going on around the corner and is able to take over some driving tasks.***

‘Day 2’ is coming! Standards are being created today.

‘Day 2’ broadens the abilities of automated mobility and its scope. The vehicle disseminates not only information about itself, it adds information about the surroundings of the vehicle, collected through its sensors. The ‘day 2’ scope is about pedestrians, cyclists, motorcyclists, vulnerable road users and unequipped road users. ‘Day 2’ is about sensing things that are beyond the line of sight. The use-cases will be based on the communication already used for ‘day 1’ and put it to extended use. ‘Day 2’ will also be robust and reach beyond mere warnings to enable semi-automated vehicle manoeuvres, such as emergency braking or cooperative adaptive cruise control, where the vehicle weaves into the general flow of traffic and anticipates movements. Use-cases such as these require highest information accuracy, functional safety, ways to address misbehaving stations, etc. All these points need to be agreed and specified by the actors who implement connected cooperative and automated driving. EuroNCAP’s ‘2025 Roadmap’ clearly supports C-ITS and sets out to set clear incentives to further support it. This raises expectations for the coming ‘2027 Roadmap’ and ‘day 2’ applications. That would further accelerate automation.

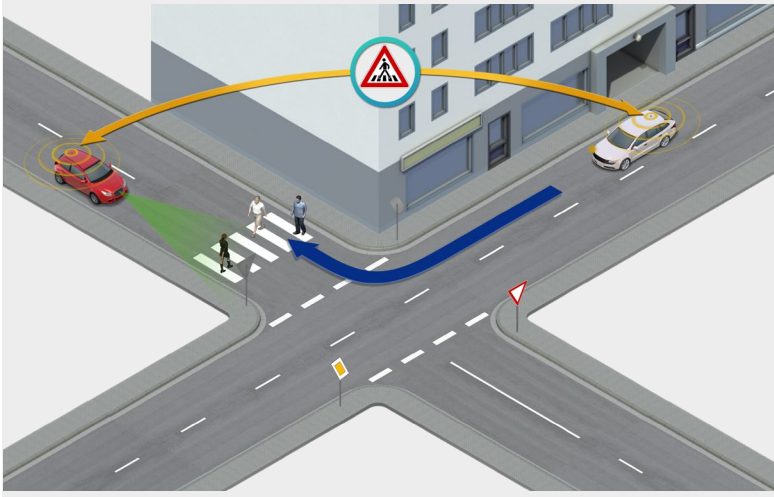
**Talking About Experience**

*The ‘day 2’ use-cases build on ‘day 1’ use-cases and extend them by enriching the information exchanged by analysis. The eyes of the vehicle connect with its sense of speaking and hearing.*

*Example - ‘Sensing Driving’ – a ‘day 2’ use-case: in this use-case a new type of message is added to the portfolio of messages that are sent short-range between actors. This use-case extends the information CAMs and DENMs make available and broadens the scope of C-ITS to vulnerable road users and/or non-equipped road users, such as cyclists, e-scooters, pedestrians or animals.*

*Collective Perception Message (CPM): Like the CAM this message is broadcast short-range. It contains information that the sensors of a vehicle gather and analyse. Vehicles share their analysis with other vehicles.*

*Key: Everybody speaks and understands the same language, functional and technical interoperability.*



**Example: Pedestrian crossing warning at urban intersection**

2

## ‘Day 3’ is the future!

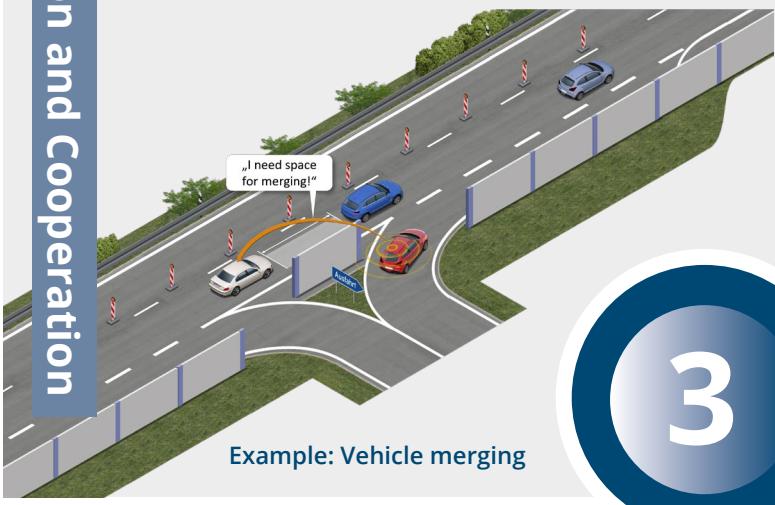
## Cooperative driving on the road to automation

***Is it still a car or would you call it a transport robot or a pod? This vehicle is capable of driving itself.***

‘Day 3’ is foreseen to base itself on ‘day 1’ and ‘day 2’. It is the cooperative communication level that would fulfil the requirements of SAE automation level 4-5 use-cases, such as cooperative automated lane change, cooperative merging amongst others. Here vehicles are technically able to make their own decisions without a human driver, based on information from other vehicles and road infrastructure.

Negotiation and Cooperation

*‘Day 3’ use-cases build upon ‘day 1’ and ‘day 2’ use-cases. Vehicles are now increasingly automated to SAE levels 3-4. They are able to make decisions themselves. C-ITS enables them to cooperate and exchange and coordinate intentions, vehicles start discussing and agreeing on traffic situations.*




Example: Vehicle merging

3

# C-ITS Eco-system

These ‘days’ depend on different actors agreeing on a long-term framework to provide for stability and for the modular ‘day-by-day’ approach to work. C-ITS relies on this eco-system, since different investment cycles call for an interoperable long-term and joint technology evolution. In the CAR 2 CAR Communication Consortium automotive manufacturers and their suppliers cooperate to agree common specifications for their C-ITS use-cases. Road authorities in C-ROADS are taking a similar function, agreeing specifications for infrastructure based use-cases.

The CAR 2 CAR Communication Consortium is an association of vehicle manufacturers, equipment suppliers, engineering companies, road operators and research institutions. Membership is open to all who are willing to share their specifications. C-ROADS is a state authority driven platform that brings state and city governments as well as road operators together to harmonise C-ITS on the road infrastructure side. Their infrastructure focused C-ITS common specifications are available to all interested parties free of charge.

C-ROADS and the CAR 2 CAR Communication Consortium work hand in hand to agree common specifications to make the ‘day-to-day’ approach to C-ITS works. C-ITS is a rules-based system to assure the long-term viability of C-ITS and serve the long-term product cycles and interests of the implementing parties. The C-ITS ‘days’ are technology agnostic and technologically open, it is the development of the rules that are the key. The EU and national regulators play key roles making certain that rules are established and observed EU wide.

# C-ITS - Regulation

The 'day 1', 'day 2' and 'day 3' all build on each other and are long-term developments. This requires from regulators:

A stable regulatory environment that allows to build the 'days' on top of each other. Annex II of the current ITS Directive provides that stability. The 'interoperability' principle makes sure every C-ITS radio beacon can receive messages from any other C-ITS radio beacon. The 'backward compatibility' principle makes sure that today's C-ITS equipped cars will be understood by future generations of C-ITS.

Radio spectrum regulation plays a key role for all radio systems deployed along roads. C-ITS needs reliable rules that assure it runs interference-free and has sufficient spectrum in the long run. Radio spectrum regulation guarantees that C-ITS fits seamlessly with other radio services required to implement EU transport policy and make road transport sustainable. Such radio services are:

1. smart tachograph, that controls that truck drivers get enough rest
2. control of the EU rules on the weight of trucks
3. road charging

***Interoperability saves lives.***
***Backward compatibility saves investments.***

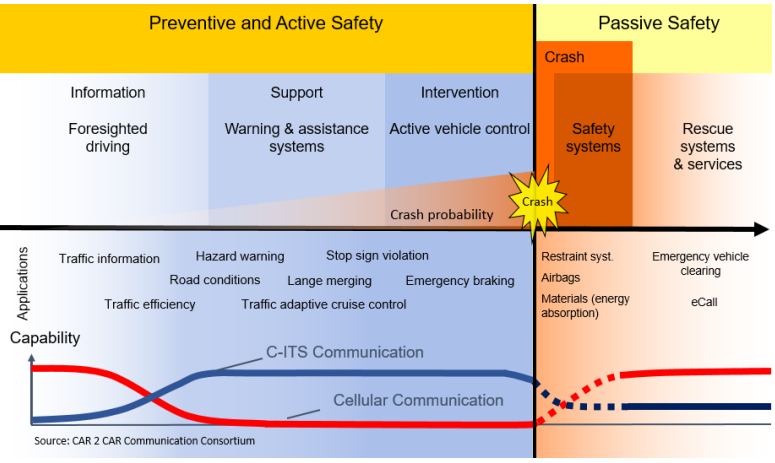



*Illustration: C-ITS and cellular communication complement each other*

# Standardisation

Automotive manufacturers and road operators prefer controllable licensing costs and work with open and interoperable C-ITS specifications, standards, testing methodologies and conformity assessment methods. Europe has a strong track record on cooperation in the field of standards.

# IP Networks

C-ITS concerns itself with warning, assistance, and intervention safety services, no matter the vehicle automation level. Only the direct vicinity of the vehicle is relevant to warn of obstacles and dangerous situations out of the line-of-sight or platooning, cooperative lane merging and others. Keys are the safety-related limited area coverage, low latency and high quality of service.

Foresighted and passive safety information exchange, such as route planning, map updates, general traffic information, require a broader view. Here a wider area coverage is most important and there are less constraints on latency or quality of service. In this case the vehicle relies on cellular connectivity to link itself with cloud services. Today existing cellular networks are used and future cellular networks are expected to offer the extended functionalities. The challenge here is to accommodate the long-term investment cycles of automotive OEM and road operators with the shorter life cycles of cellular communication generations. Connectivity needs to be maintained during a vehicle's lifetime.

The figure on the left illustrates the complementary operation of direct vehicle to everything (V2X) communication and standard cellular communication. Together they are required to support the varying services fulfilling the shared public mission of increasing road safety and greening mobility.

# The business case & earning public confidence

The path to automation is a long one and the enthusiasm of the early 2010s has cooled to a more realistic view. It is increasingly clear: A mere set of sensors in a vehicle may not come to grips with complex transport environments to assure automation levels SAE level 4 or higher. Hence the business case for automation goes beyond a single automotive vehicle manufacturer. Automation won't move homogeneously across all driving environments at once. Urban environments prove far more challenging than expected. Views on the commercial viability shift: will it be the last mile that makes the difference or hub-2-hub operations? Passengers? Freight? Individual ownership? Managed fleets? Our perception has moved from technology driven excitement to the realisation that it is governance that keeps automation ticking.

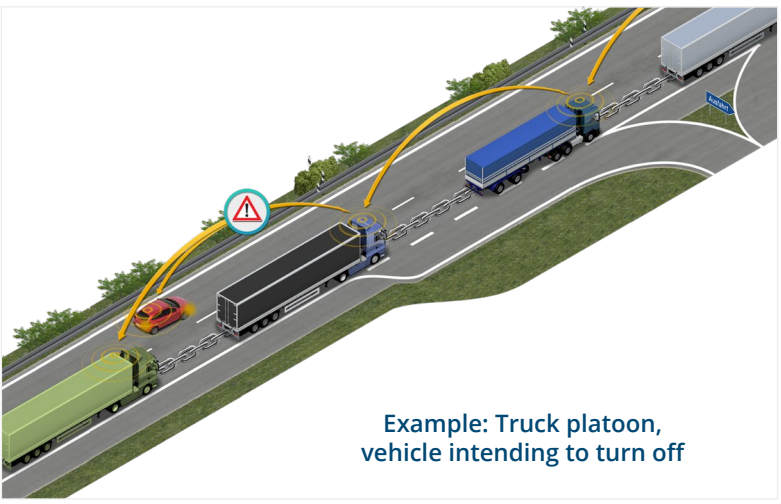
The commercial case is still compelling, it just will not be that easy to capitalise upon. Freight transport is in increasing demand, from individual urban deliveries to inter-urban. Shippers spend more money than ever, a trend only accelerated by the COVID pandemic. At the same time less and less young people decide to become drivers and driver shortage is becoming a bottleneck. In Europe the cost per km is estimated to around 1 EUR/km, around 40% of which is related to drivers.

The savings that fully automated trucks without drivers or truck trailer combinations with less drivers promise is an incentive that attracts venture capital, as well as entrepreneurs from AI to logistics.

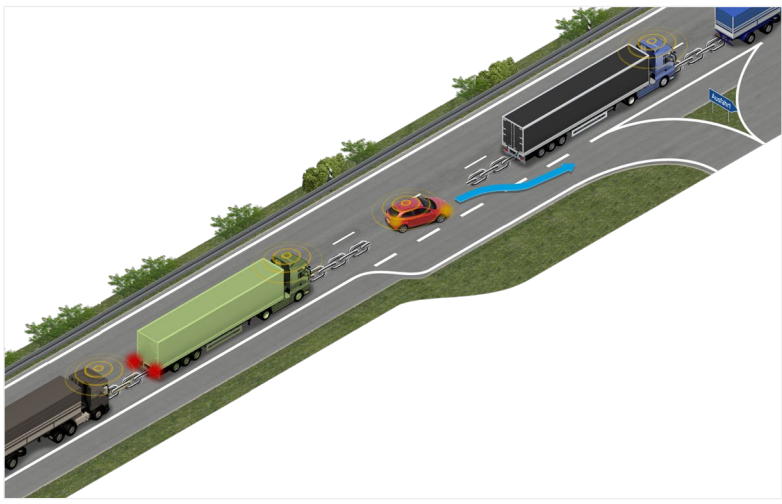
Confidence in the broader public in automation is by no means a given and needs to be earned. Here highest levels of safety are a minimum requirement, just as is already the case with vehicles today. The case for automation is as solid as it was 10 years ago, just more sober.

We believe that automation will be built in an incremental evolutionary process and requires governance that considers that vehicles have long life cycles and must meet highest safety standards.

We believe in an evolutionary process, where the core applications and services that affect the safety of road users, no matter if bicycles, motorcycles or pedestrians, build upon each other. That what we launch now will be building blocks for applications to come and still make a valuable contribution to road safety, even when the vehicles equipped today will one day in the future meet vehicles with far advanced automation levels.



Example: Truck platoon, vehicle intending to turn off



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