# State of the art in autonomous driving

German Aerospace Center *DLR*

Institute of transportation systems

Smart Cities Symposium Prague 2017

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DLR

# DLR at a glance

Deutsche Zentrum für Luft- und Raumfahrt (DLR)

***German Aerospace Center***

- *8000 employees*
- *20 locations in Germany*
- *Outside Germany: Brussels, Paris, Tokyo and Washington D.C.*

Aeronautics

Space

Energy

Transport

Institute of transportation systems:

- Automotive
- Railway Systems
- Traffic Management

# Why Autonomous Vehicles?

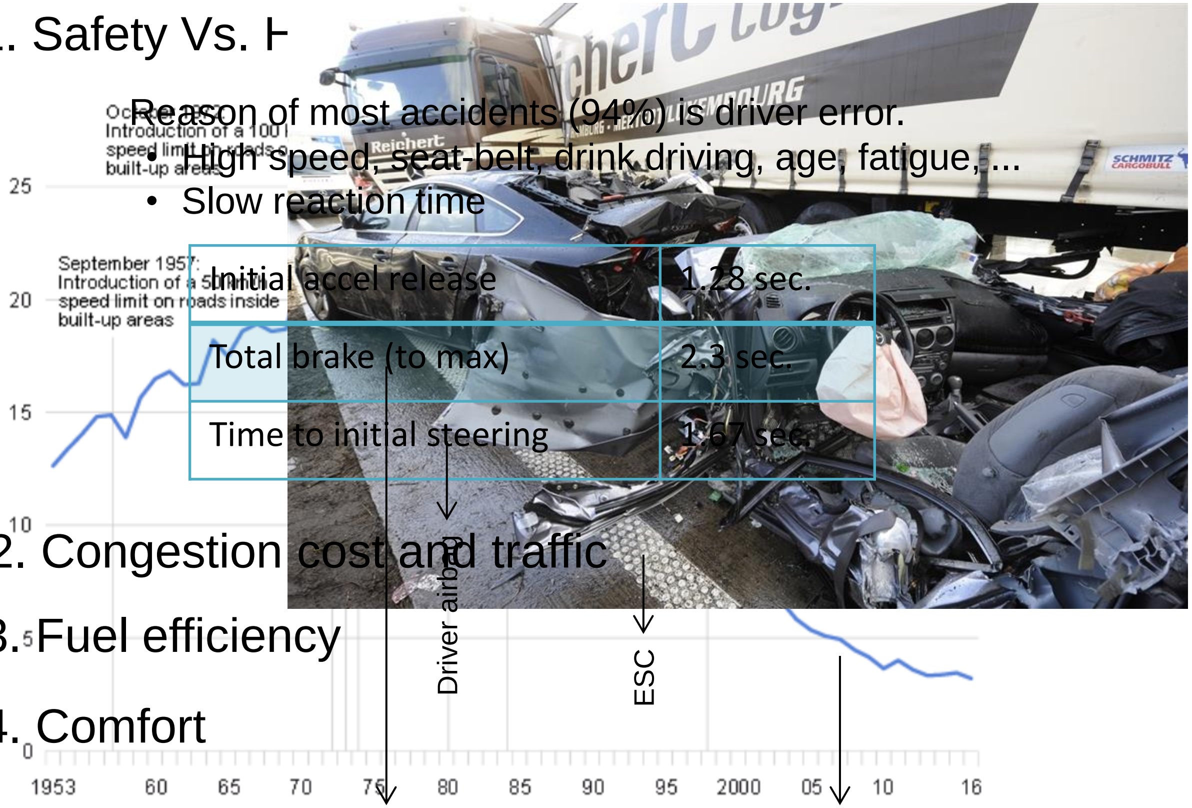
**Trend in the number of persons killed in road traffic accidents**
Thousand

1. Safety Vs. H

Reason of most accidents (94%) is driver error.

- High speed, seat-belt, drink driving, age, fatigue, ...
- Slow reaction time

| | |
|---|---|
| Initial accel release | 1.28 sec. |
| Total brake (to max) | 2.3 sec. |
| Time to initial steering | 1.67 sec. |




2. Congestion cost and traffic

3. Fuel efficiency

4. Comfort

…

2016 = 3.2 (preliminary)

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# Autonomous vehicles from illusion to reality

- First idea: In the World’s Fair of 1893 in New York, General Motors presented vision of “driverless cars”.

- Three main stages of research:
  - 1980-2003 : University researchers developed *AVs* in two groups
    - Dumb vehicle, smart dedicated lanes →Vehicle relies on infrastructure
    - Automated vehicles
  - From 2003 : *DARPA Grand challenges* boosted research
  - Recently private companies and vehicle industries have advanced *AVs*


# Different level of automation

| | |
|---|---|
| Level 0 | No Automation |
| Level 1 | Driver Assistance |
| Level 2 | Partial Automation |
| Level 3 | Conditional Automation |
| Level 4 | High Automation |
| Level 5 | Full Automation |


Driver monitors driving environment

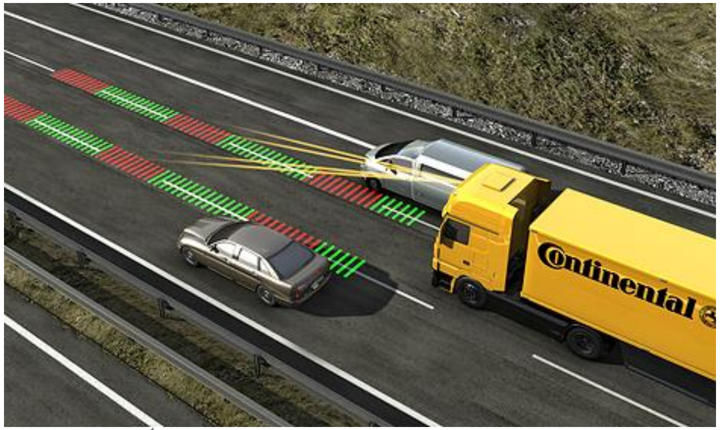
Electronic system monitors driving environment

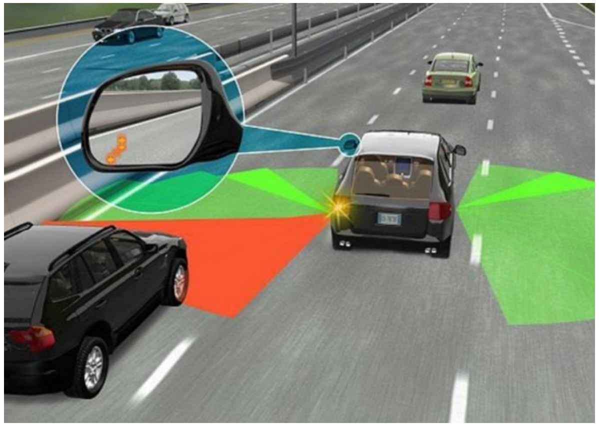
SAE international's J3016

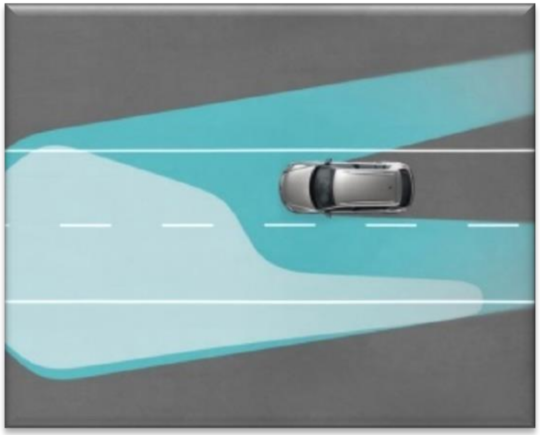
# Different level of automation

| Level | Name | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of dynamic driving task | System capability (driving modes) |
|---|---|---|---|---|---|
| **0** | **No Automation** | Human driver | Human driver | Human driver | Some driving modes |

- Examples *(Series production)*: Lane Departure Warning, Forward Collision Warning, Blindspot Detection, Lane Change Decision Aid, Parking Sensors, Adaptive Front-lighting



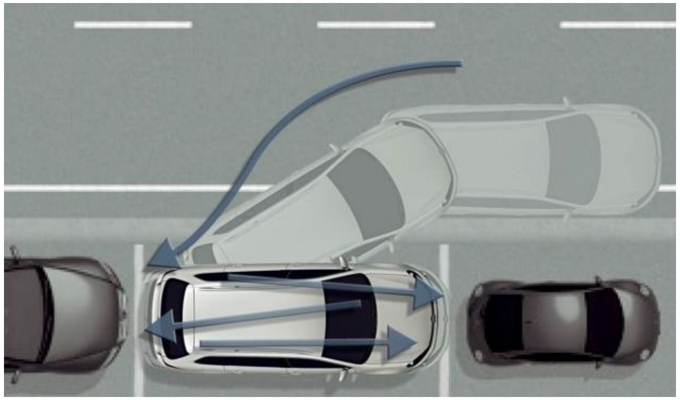





# Different level of automation

| Level | Name | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of dynamic driving task | System capability (driving modes) |
|---|---|---|---|---|---|
| **1** | **Driver Assistance** | Human driver and system | Human driver | Human driver | Some driving modes |

- Examples *(Series production)*: Adaptive Cruise Control, Parking Assist (only lateral control)



# Different level of automation

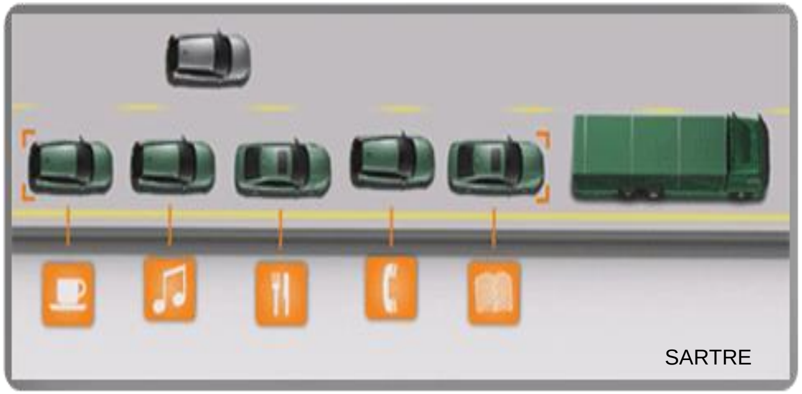
| Level | Name | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of dynamic driving task | System capability (driving modes) |
|---|---|---|---|---|---|
| **2** | **Partial Automation** | System | Human driver | Human driver | Some driving modes |

- Examples *(Series production)*: Traffic Jam Assistant, Parking Assist (longitudinal and lateral control), Tesla Autopilot

# Different level of automation

| Level | Name | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of dynamic driving task | System capability (driving modes) |
|---|---|---|---|---|---|
| **3** | **Conditional Automation** | System | System | Human driver | Some driving modes |

- Examples *(Research & Development)*: Highway Chauffeur, Platooning




# Different level of automation

| Level | Name | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of dynamic driving task | System capability (driving modes) |
|---|---|---|---|---|---|
| **4** | **High Automation** | System | System | System | Some driving modes |

- Examples *(Series):* People Mover (on constructional separated lanes), Automated transport of goods on factory premises
- Examples *(Research & Development)*: Google car, People Mover (on public roads), Automated Valet Parking, various research projects

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# Different level of automation

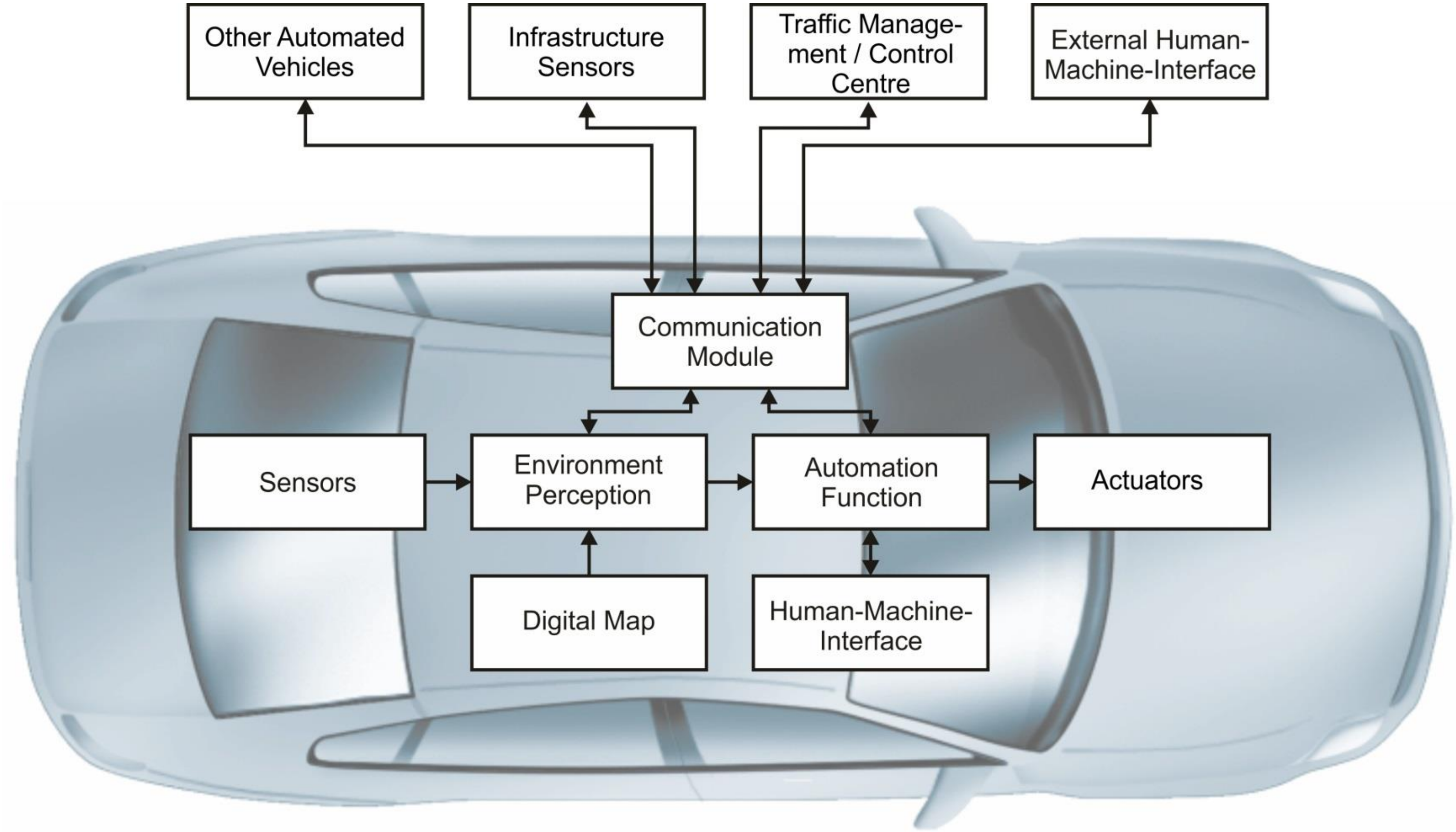
| Level | Name | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of dynamic driving task | System capability (driving modes) |
|---|---|---|---|---|---|
| **5** | **Full Automation** | System | System | System | All driving modes |

- A vehicle with an automated driving system that, once programmed with a destination, is capable of fully performing the dynamic driving task throughout complete trips on public roadways, regardless of the starting and end points or intervening road, traffic, and weather conditions.

- Degree of maturity: Research

- Currently no systems available, which are capable of this.

# Technological basis for automated driving



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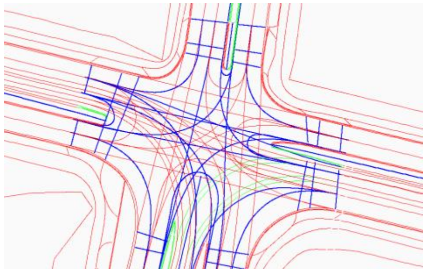

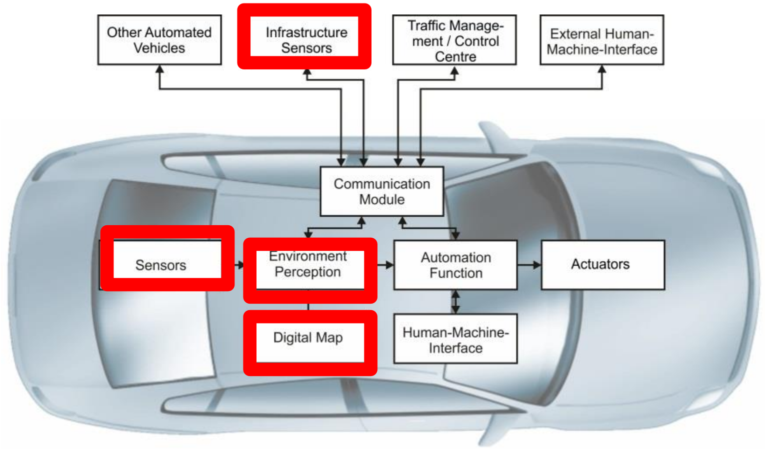


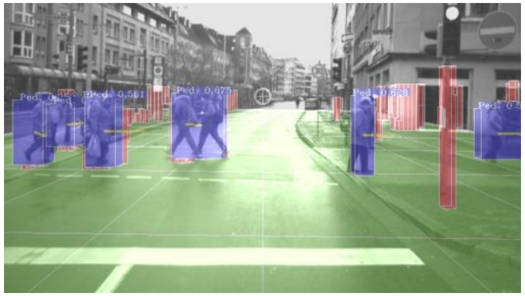

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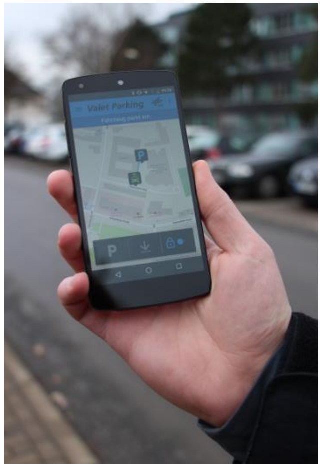

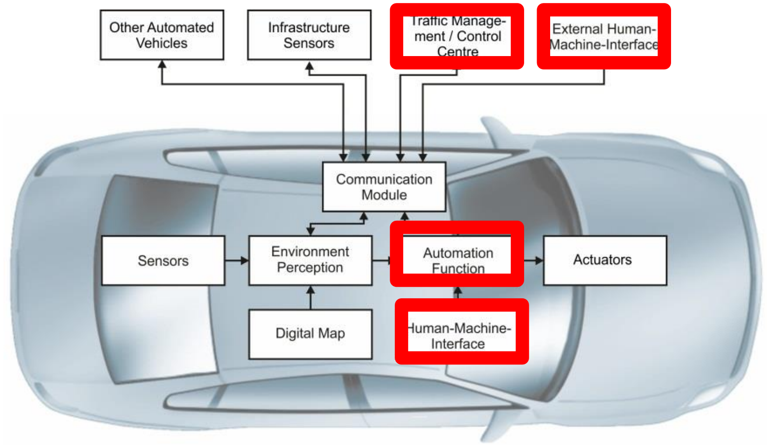


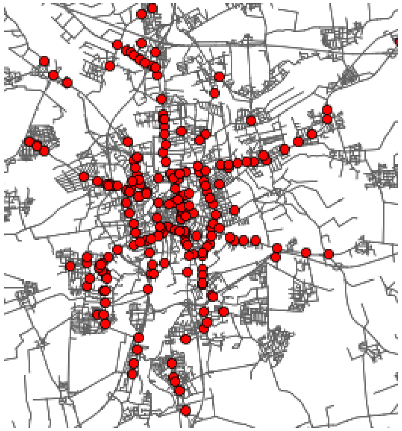

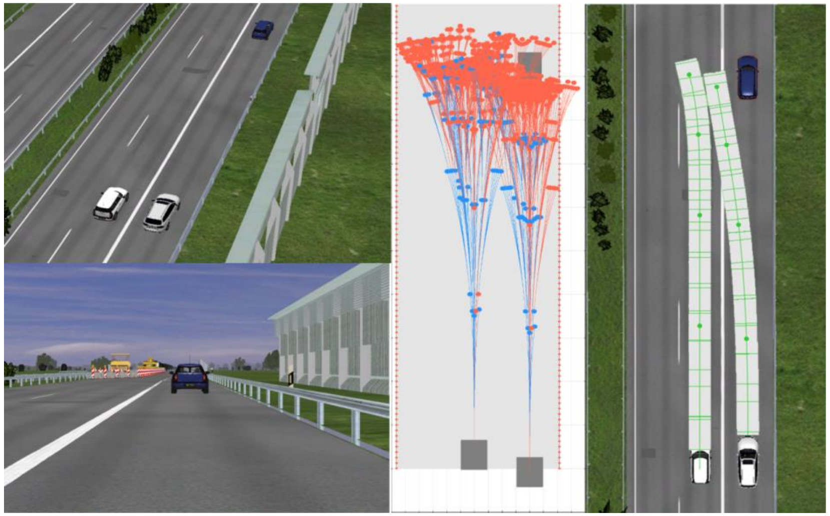

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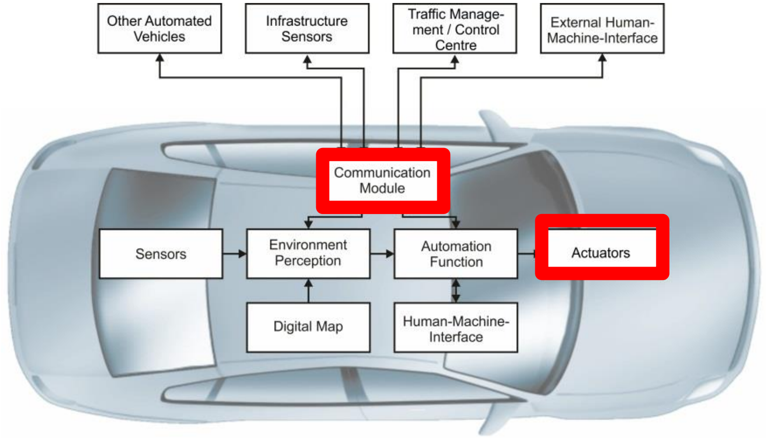
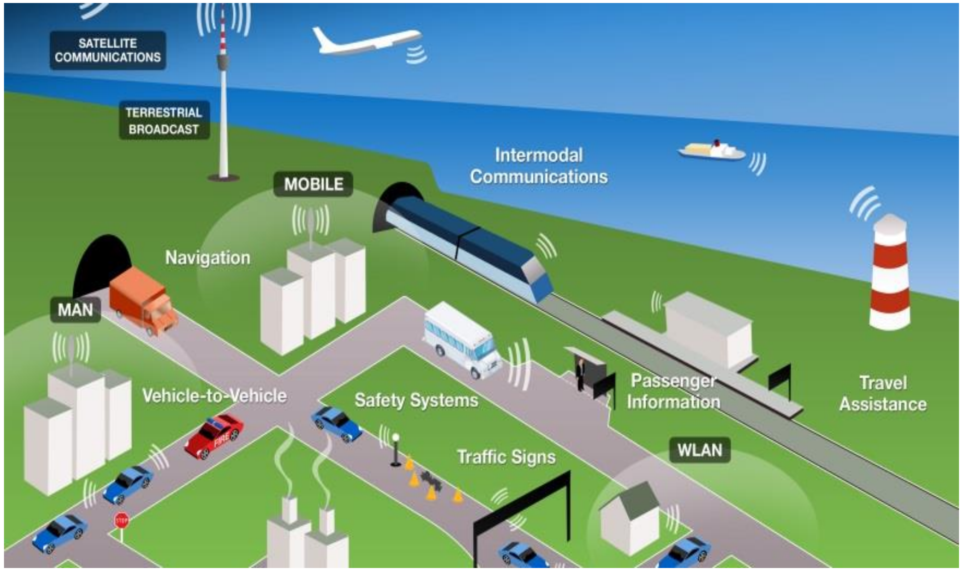


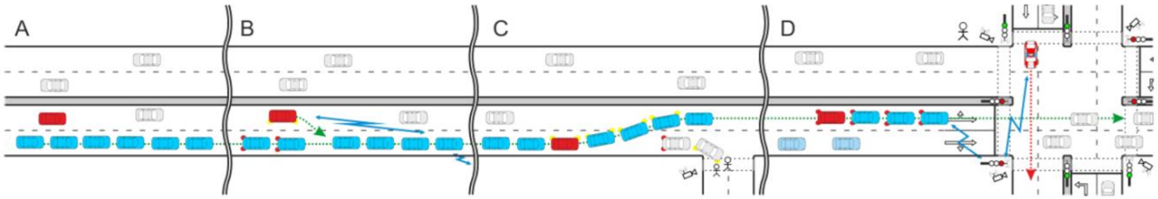



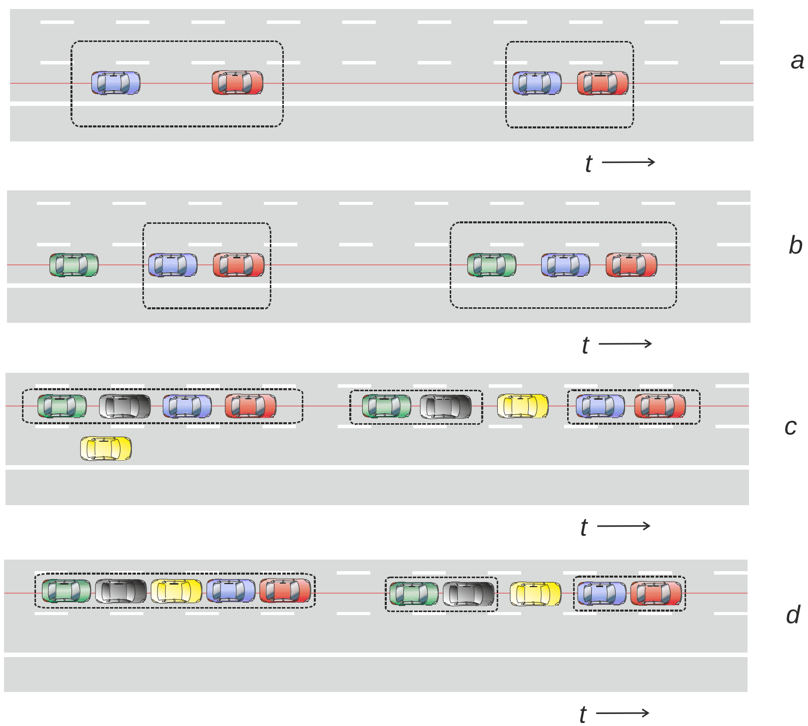
# Cooperative lane changing with V2V communication

# Highly-automated valet-parking

# Outlook

## Managing Automated Vehicles Enhances Network (MAVEN)

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