Development of An Integrated Transportation System of Connected Automated Vehicles and Highways

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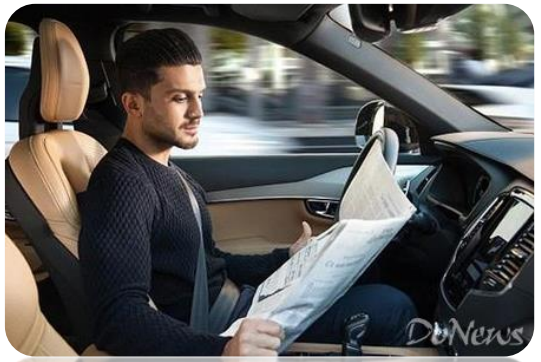
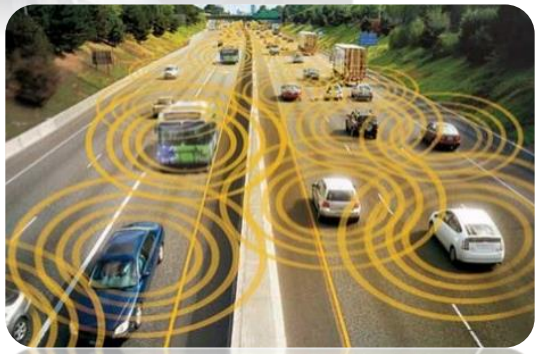
Connected Automated Transportation System Terminology

- Connected Automated Transportation System (CATS)
  - Connected Automated Vehicle Highway (CAVH)
  - Intelligent Connected Transportation System (ICTS)
- Internet of Vehicle
- Connected Vehicle (CV)
- Autonomous Vehicle (AV)
- Automated Vehicle
- Connected Automated Vehicle (CAV)
- Driverless Vehicle
- Automated Highway System (AHS)

Connected Automated Vehicle Highway (CAVH) System — Definition

- Use I2X and V2X communication and information interchange with arranged communication protocol and data interchange
- Achieve intelligent transportation management, intelligent dynamic information services, and automated driving
- Ultimate form of development of Intelligent Transportation System





Connected Automated Vehicle Highway System
— Key Technologies

Connected and Automated Vehicle

- IOV Safety Tech
- Telematics
- CAV
- Automated Vehicle

Connected and Automated Highway System

- Internet of Highway
- I2X and V2X
- Active Management
- Automated Highway System

AHS Demo – San Diego 1997

- Demonstration Project of AHS in San Diego

Development Directions of CAVH

Vehicle Based Approach

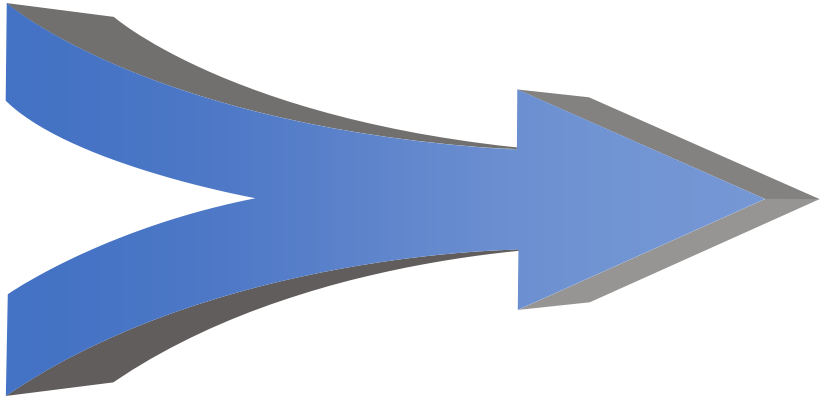
IT & OEM Firms

Connected and Automated Vehicle

Infrastructure Based Approach

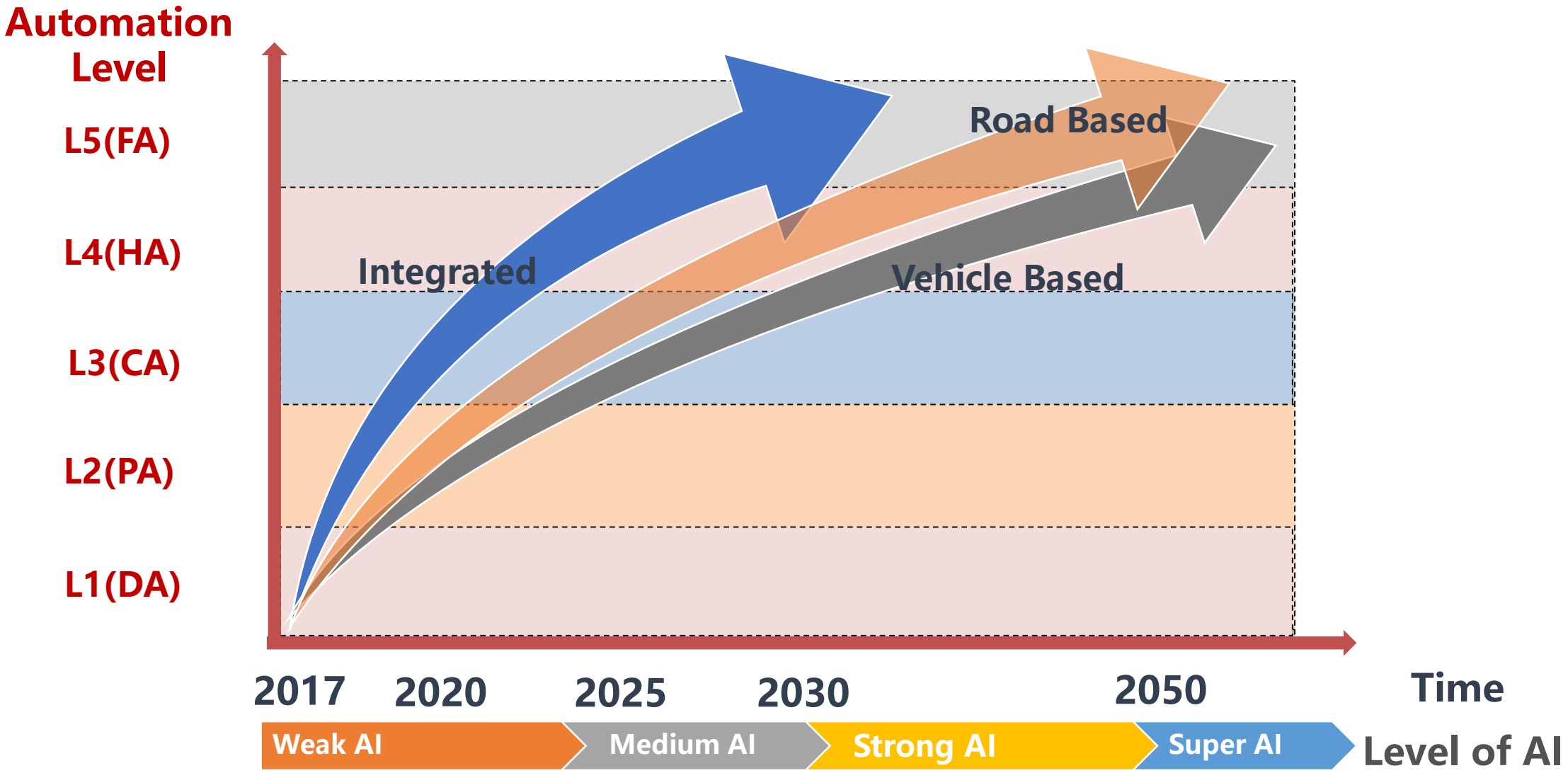
Transportation Industry

Connected and Automated Highway Systems



CAVH

Integrated Development of CAVH in the Future



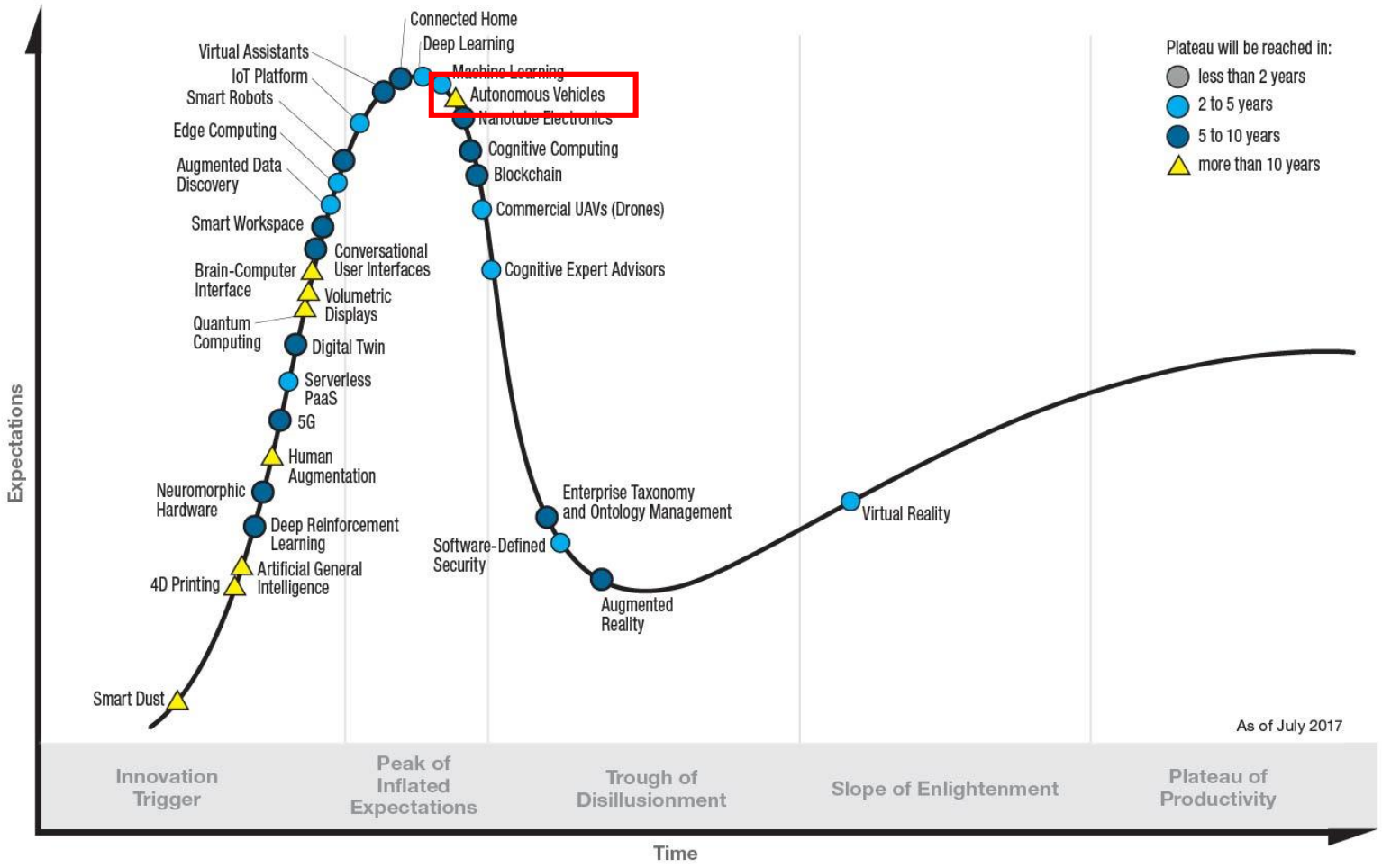
Three Vehicle Based Approaches for Automated Driving in the World

- Google/Waymo – Automated, Not-connected
- Tesla – Automated, Connected
- Uber/Volvo – Automated, Connected, Shared

Characteristics and Drawbacks

- **Medium and strong AI** technologies are necessary. It could be achievable in large scale around 2035
- Extremely smart vehicle is necessary. Vehicle fully controls driving and dominates decision making
- Highway infrastructures do not work for automated driving or only assists automated driving
- The **sensors** such as LIDAR, Video, Millimeter radar, Ultrasonic radar and **computing** systems are **very expensive**
- Safety and reliability are not appropriate

Gartner Hype Cycle for Emerging Technologies, 2017



gartner.com/SmarterWithGartner

Source: Gartner (July 2017)

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Gartner

System Based Approach：Simple Vehicle , Smart System (Simple Vehicle , Smart Road)

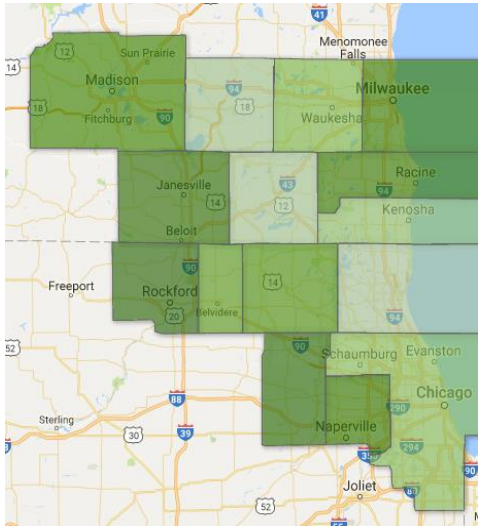
Technical Features：

- The majority of the sensor functions can be achieved using sensor systems on highway infrastructure or vehicle/highway system
- The majority of the vehicle operation and control functions can be achieved via the cooperation of control systems on highway infrastructure and vehicle
- Multiple redundant systems for sensor system, computing system, control system, communication system, information safety

Implementation Cost Analysis – WI & IL

- Triangle Area: Southern Wisconsin + Northern Illinois
  - 2.4% of national highway system mileage
  - 3.4% of national vehicle ownership
  - ROI comparison

    (system based approach vs. vehicle based approach)

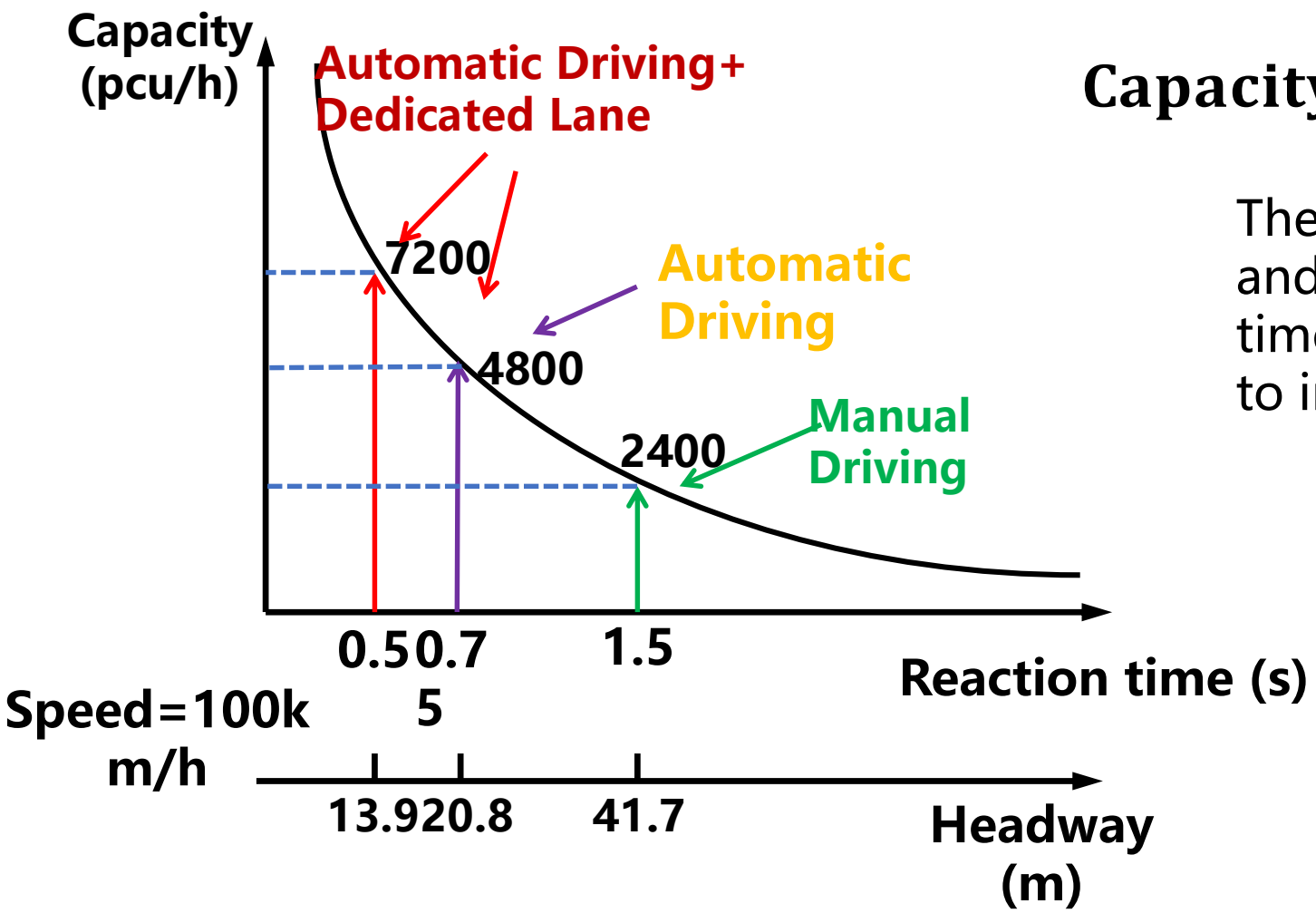


Area	Vehicle Ownership (million)	Interstate Highway Mileage (mi)	ROI (Interstate only)	Interstate + Major US Highway Mileage (mi)	ROI (Interstate + US Highway)
Southern Wisconsin (8 counties)	2.7	280	2,566 : 1	845	850 : 1
Northern Illinois (7 counties)	7.7	377	5,468 : 1	424	4,860 : 1
Combined Area	10.4	657	4,232 : 1	1,269	2,192 : 1

Advantages of CAVH

- Focus on Transportation Problems and Optimization, not only a vehicle automation problem
- Transportation agencies owns Right of Way and infrastructure and can play a key role in planning, design, deployment, and operations of CAVH
- Cost effective way to implement
- New standard highway and infrastructure system for all types of automated vehicles
- Hierarchical TOC provides the higher level of management for all vendors' fleets and travelers
- For vehicle-based approach, agencies could only play a supporting role

Increase Highway Capacity



Space headway with different reaction times

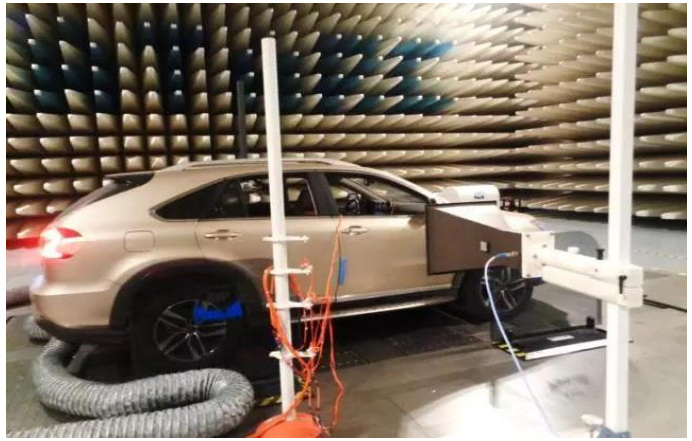
$$\text{Capacity(veh/h)} = \frac{3600}{\text{Reaction time(s)}}$$

The combination of automatic driving and dedicated lane reduces reaction time and headway significantly, so as to increase highway capacity

Reference : Ran B. and Tsao H.S.J. "Traffic flow analysis for an automated highway system." (1996).

Joint Research Institute on Internet of Mobility
Between
Southeast University and
University of Wisconsin-Madison

National IOM Demonstration Area Establishment



China Automotive Technology & Research Center

CATARC

CATARC Test Site for Internet of Mobility at Yancheng City

National IOM Demonstration Area Establishment

Multi DOF Driving Simulator at SEU

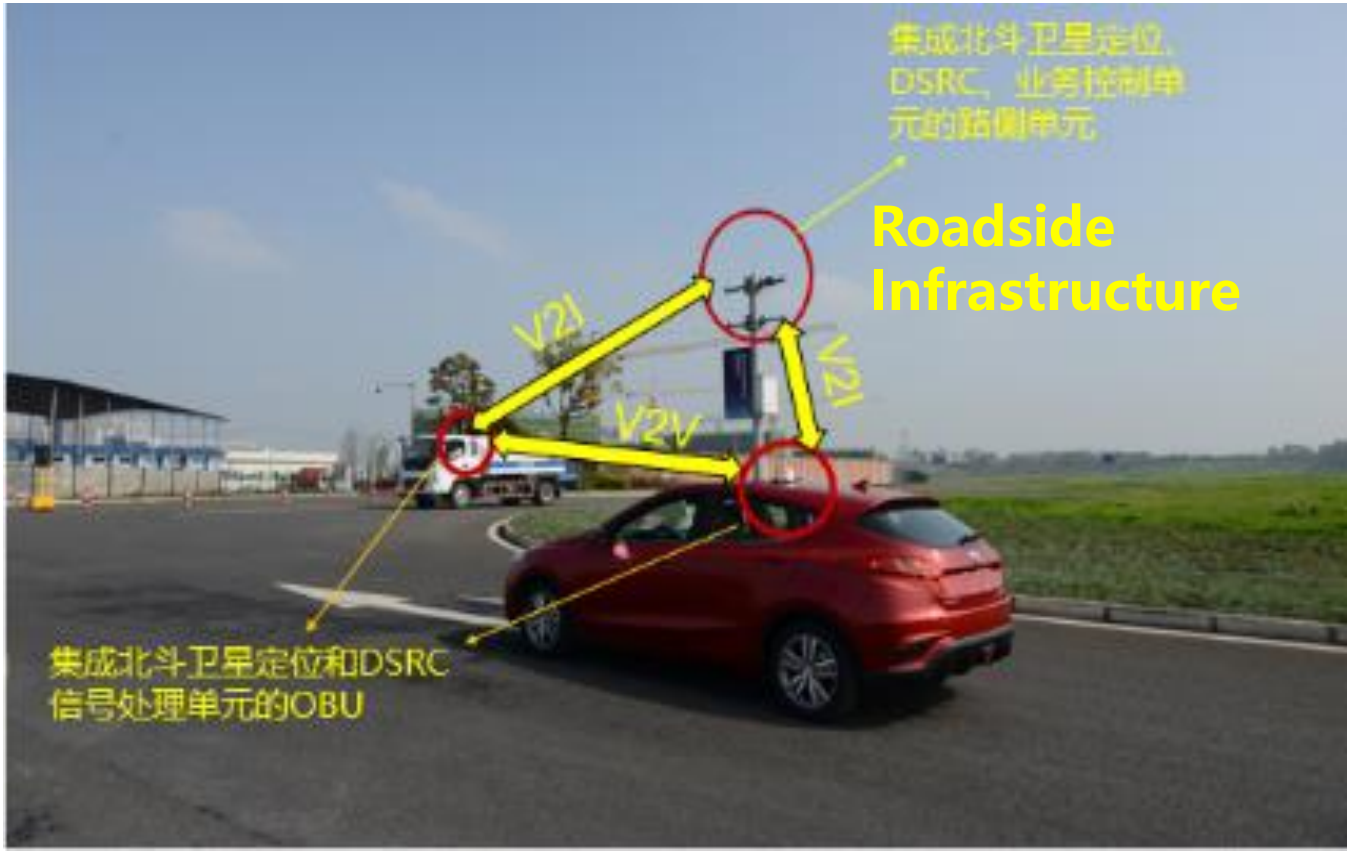
Demonstration of Dedicated Lanes for CAVH System in China

Target: Level 3 Automation

Demo Expressway

Demo Vehicles - Automobiles

Roadside Infrastructure & Telecommunication



4G
LTE
/DSRC

5G/4G
LTE
/DSRC