Automated Highway and Self-driving car

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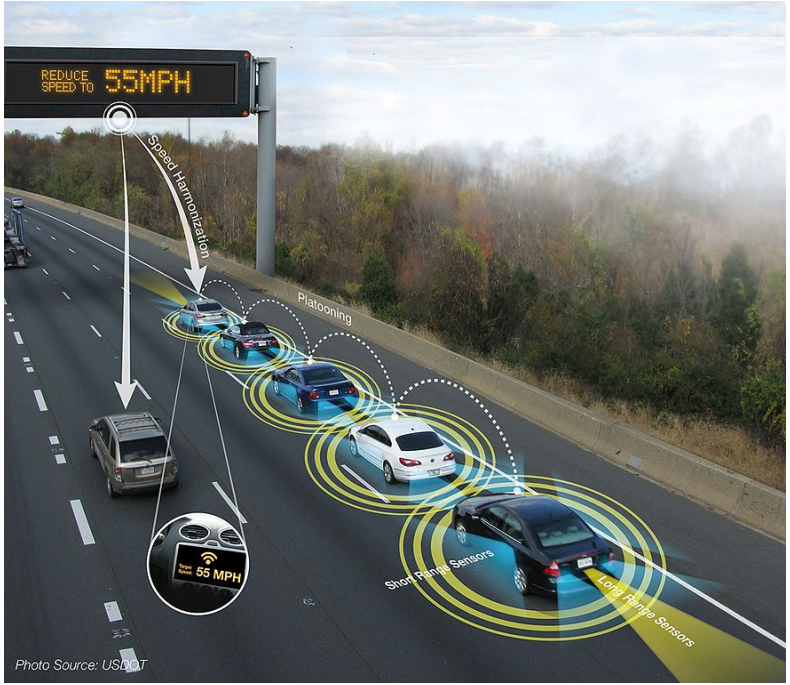
The advantages of **automated highway** system can be achieved by **self-driving** car at a lower cost and less need for infrastructure.

Automated Highway

The approach of autonomous driving in 1990s



What is automated highway system (AHS) ?

A set of **designated lanes** on a **limited access** roadway where **equipped vehicles** are operated under **completely automated** control

In 1995, National Automated Highway System Consortium (NAHSC) tested demo on I-15 HOV lanes in San Diego.

Benefit: Automated highway system can increase road capacity and safety.

Reduce vehicle crashes per highway kilometer by as much as **50 to 80 percent**
NAHSC Analysis

The max traffic flow of AHS is **5500** veh/hr/lane which is **3 times** greater than the maximum of human driver in simulation. (Data in **1995**)

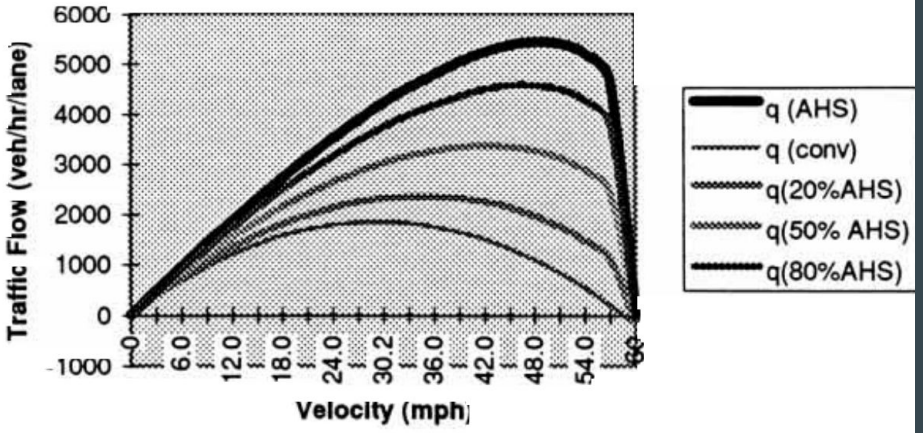
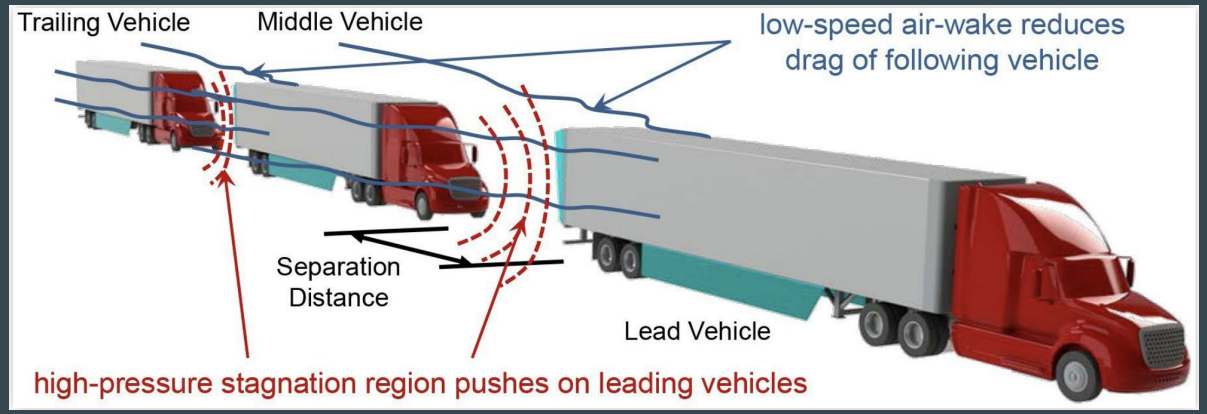


FIGURE 1 Flow-velocity relationship for different combinations of AHS and conventional traffic.

Benefit: Automated Highway increases fuel efficiency.

The figure is from a **three-truck platooning** test. The average **fuel savings** at the speed of 65 mph are range from **10 to 20 percent** depending on the interval between them.

AHS can bring more cars into platooning, making the middle cars drafting which can save more fuel.



Drawback: Automated highway is too expensive.

Method 1: **Converting** the left-most lane into an AHS lane in a highway (digits on the left)

Method 2: Add **elevated lanes** in road center. (digits on the right)

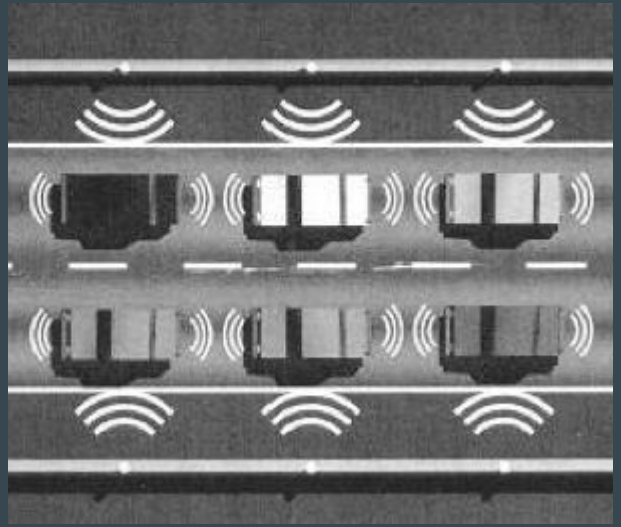
Road cost: **60,000 - 2,350,000** dollars/year/km

Long-term cost: **785,000 - 336,000** dollars/year/km

Traffic flow: **4,000 - 5,500** vehi/hour/lane

Conventional: **2,000** vehi/hour/lane

Prices are converted from 1994 USD



Self-driving Car

Recent technology benefit from tremendous increase of computing power

Relationship: AHS is the predecessor of autonomous driving, due to insufficient computing power in 1990s.

Computing power:
< 1 GFLOPS

Used for AHS

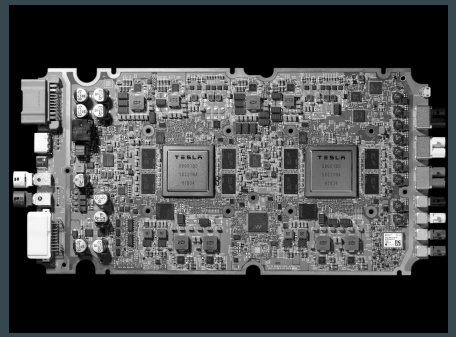
MIPS R4000 CPU

Released in **Oct 1991**

Capable of

Real-time simulate simple route of 70 cars on AHS

Store simple status of 2000 cars in 50 miles



Computing power:
1200 GFLOPS

Used for self-driving car

Tesla Driving Computer

Released in **Apr 2019**

Capable of

Process video from several cameras, recognize all the objects around car

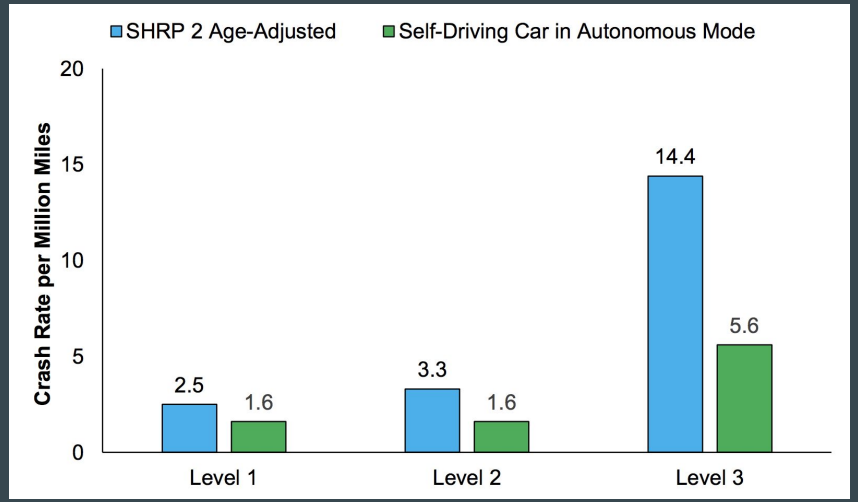
Simulate detailed trajectory of surrounding cars and itself

Safety: Current self-driving car is **safer** than human driver, but is not as safe as AHS.

The figure shows the self-driving has **lower** crash rate in very levels of crash.

The estimated crash rate of automated highway is **20 to 50 percent** of manual car's crash rate.

Theoretically, automated highway has lower casualties rate, ranging from **0.2 to 6 casualties per 100 crashes** depending on road condition. (human **6%**, no data for self-driving cars)

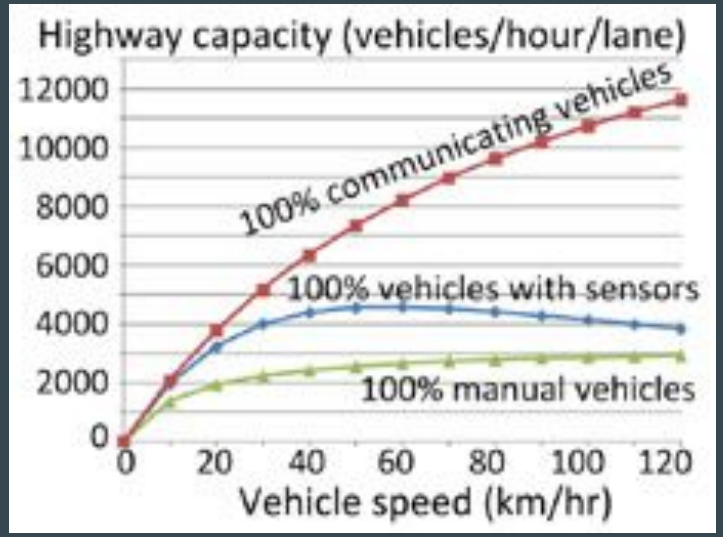


Capacity: The road capacity will increase to **2.73** times with self-driving cars, **5** times when all cars are capable of communicating each other.

Self-driving car has less reaction time than human driver, so it decreases the distance between vehicles.

When all the cars are capable of communicating each other, it will be **very similar** to AHS.

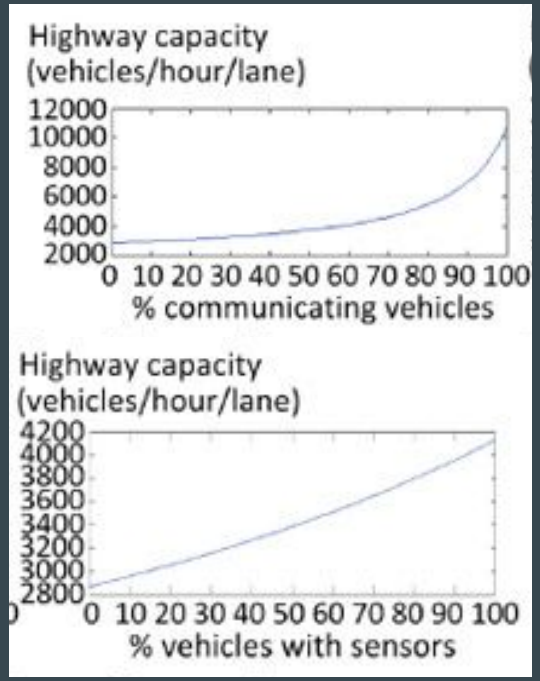
5 times is the data in 2012, and **3 times** is the data in 1990s. It is because modern computer runs faster, shortening the interval between vehicles.



Adaptability: Self-driving car can drive on manual lanes, and we can **gradually** increase its proportion on road to achieve high capacity.

One difference is that self-driving can **gradually increase** its proportion on the road, while all vehicles in AHS lanes **must be modified**.

Traffic flow of communicating car is less than sensor-based car when the portion is less than **20-30%**, but grow much faster after **80%**.



Cost: Self-driving car is cheaper than automated highway.

Self-driving car does not need new infrastructure.

When 1 kilometer of highway is filled with self-driving cars,

Sensor-based self-driving car:

197,500 dollar/year for traffic flow of **4,150**

Communicating self-driving car:

482,000 dollar/year for traffic flow of **11,000**

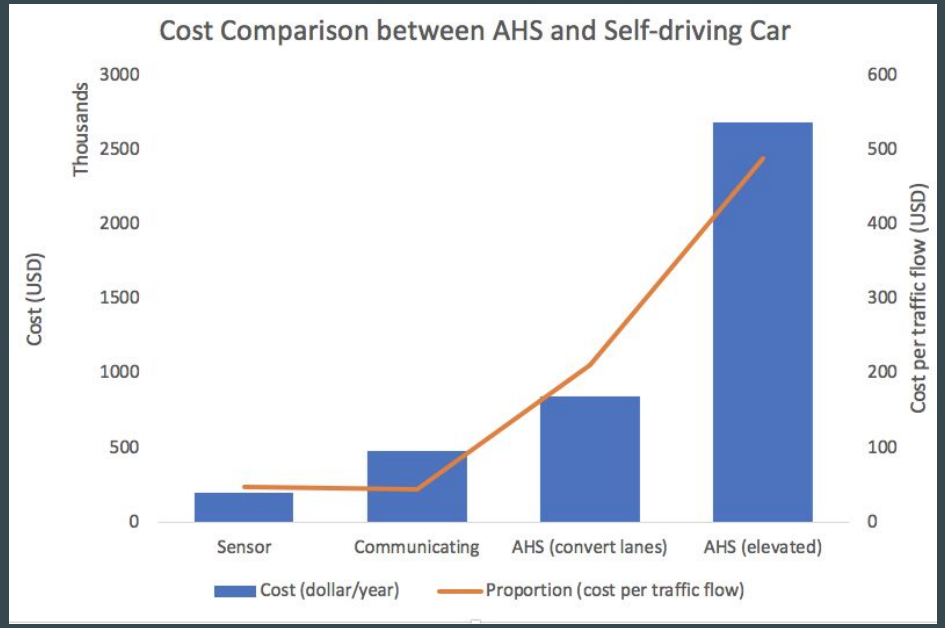
AHS (convert lanes):

845,000 dollar/year for traffic flow of **4,000**

AHS (elevated):

2,686,000 dollar/year for traffic flow of **5,500**

Unit of traffic flow: vehicle/hour/lane



Progress: Self-driving car progresses much faster than AHS.

Most of automated highway system research stopped before 2000.

Waymo, the leading company in fully autonomous driving, has already tested more than **10 million** miles.

Level-2 self-driving technology from Tesla, Autopilot, has been commercialized for 5 years.

In conclusion, automated highway versus self-driving car

Similarity	Difference
Increase road capacity	Self-driving is cheaper
Increase fuel efficiency	Self-driving is more adaptable
Safer than human driver	Self-driving has more road capacity
More leisure time for driver	Self-driving need more computing power
More expensive than manual car	Current self-driving is not as safe as AHS

Self-driving replaced the position of automated highway and will be the future solution to road traffic.

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