How Might Connected Vehicles and Autonomous Vehicles Influence Geometric Design?

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Abstract

With the continued research on connected and autonomous vehicles showing promise for implementation, how may this influence the future of geometric design of our roads and highways? This paper examines various horizontal, vertical, and cross sectional elements used in design today and how they may be influenced by these new technologically advanced vehicles (Figure 1).

Figure 1 Autonomous Vehicle Source Bigstock.com

The Driver

There are many types of drivers on the road today. There are those that could be considered poor drivers or even impaired drivers (Figure 2). There are also exceptionally skilled drivers (Figure 3). Younger drivers have less experience, misjudge risks, and may be pressured by peers (Figure 4). Aging drivers may have decreased vision, physical abilities, and diminishing cognitive abilities.

Figure 2 An Impaired Driver Source: Bigstock.com

Figure 3 Highly Skilled Driver Source: Bigstock.com

Figure 4 Younger Distracted Driver Source: Bigstock.com

Types of Roads

High Speed, low speed, few access control points, many access control points are all possible road types. For all types of roads, sight distance is an important design criteria.

Stopping Sight Distance (SSD)

SSD is the distance required to perceive an object in a roadway and bring the vehicle to a stop. SSD is used by the engineer to impact numerous components along the road. Equation 1 is the traditional formula for Stopping Sight Distance (SSD) for level roads.

$$SSD = 1.47\ Vt + 1.075\frac{V^2}{a} \qquad \text{(Equation 1)}$$

Where: SSD = stopping sight distance, ft
V = design speed, mph
t = brake reaction time, **2.5s**
a = deceleration rate, ft/s^2

Remove the Human Driver

AV technology can communicate with its environment 10 times per second under test conditions. If we remove the human driver from the SSD equation and replace that driver with the AV technology, the brake reaction time could significantly decrease. See Table 1 for reduction of the brake reaction time to 1 second and to 0.3 second.

Table 1 Comparison of SSD and Brake Reaction Times of 2.5s, 1s and 0.3s

Design Speed	t	SSD Calculated	t	SSD Calculated	t	SSD Calculated
MPH	Seconds	Feet	Seconds	Feet	Seconds	Feet
40	2.5	300.6	1	212.4	0.3	171.2
50	2.5	423.7	1	313.5	0.3	262.0
60	2.5	566.0	1	433.7	0.3	372.0
70	2.5	727.6	1	573.2	0.3	501.2

In the second part of Equation 1, 1.075 (V^2/a) is the distance the vehicle travels while the brakes are applied. The deceleration rate in this equation is based on 11.2 ft/s^2 which is the comfortable deceleration rate for approximately 90% of the drivers. The AV vehicles could be programmed to provide a greater deceleration rate.

Lanes, Shoulders, and Roadside

If the vehicles are sensing lane lines and other objects (adjacent vehicles and barriers), do we need as much space in a lane or between vehicles? How close could vehicles get to one another side by side? The design width for passenger cars is 7.0 feet and most buses and trucks are on the order of 8 to 8½ feet wide. Could this lead to narrower lanes and less pavement (Figure 5)? Would shoulders be needed? Could we eliminate most, perhaps all, roadside safety features such as guardrail, attenuators, and barriers? We could build steeper slopes without clear zones or barrier (Figure 6).

Figure 5 Narrow Flex Lane. Source: FHWA, http://www.ops.fhwa.dot.gov/publications/fhwahop10023/chap2.htm

Figure 6 Steeper Roadsides That May No Longer Warrant Barrier Protection Source: FHWA http://www.fhwa.dot.gov/engineering/geotech/pubs/nhi10024/nhi10024.pdf

Intersections and Parking

With the AV sensing other vehicles and communicating with other vehicles, there is the potential to eliminate stop signs and traffic signals. Intersection delay should decrease and capacity of each lane should increase. If we go to shared use AV, would driveways be needed at homes (Figure 7)? Would AV vehicles park at stores and other locations, or would they just drop off the occupants go to a nearby parking area and then come back and get the passengers or be rerouted to pick up others? Could this reduce the amount of on-street parking (Figure 8)?

Figure 7 Are Driveways Needed? Source Bigstock.com

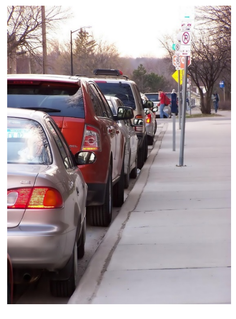

Figure 8 Would On-Street Parking Be Needed? Source Bigstock.com

Figure 9 Maintenance Vehicles Source Bigstock.com

Other Considerations and Conclusions

What will be the impacts to work zones? How will maintenance be impacted (Figure 9)? Design changes are not expected until traditional vehicles are removed from the stream of CV/AV vehicles.