How Might Connected Vehicles and Autonomous Vehicles Influence Geometric Design?

October 10, 2017
Overview

- Design Vehicle
- Design Driver
- Potential Geometric Impacts of Autonomous Vehicles
Connected Vehicles

- Advanced sensors
- Wireless communications
  - V2V
  - V2I
  - V2D

Autonomous Vehicles
How may they impact geometric design?

What is an autonomous Vehicle?
From Wiki: “…a vehicle that is capable of sensing its environment and navigating without human input.”
Components of the Highway System

- **Road**
  - physical features such as geometry, pavement, etc.
  - environmental features such as light, weather, etc.
  - operational features such as traffic control, speed control, etc.

- **Vehicle**
  - physical features such as geometrical dimensions
  - mechanical performance

- **Road Users (e.g. drivers, pedestrians)**
  - knowledge of the system (result of previous experience and training)
  - physiological characteristics (e.g. hear, see)
  - skills and attitudes (ability to act upon attained information and/or prior knowledge)
How Do We Choose a “Design” Driver?
Young Drivers

Undeveloped Capabilities

- Lack Experience
- Misjudge Risks
- Pressured by Peers
- Largest Age group to lead to a fatal crash by Driver Error
Aging Drivers

Diminished Capabilities
- Visual
- Mental (cognitive)
- Physical

• Americans aged 85 and older are the fastest growing part of the population.
• By 2020 one in five people will be aged 65 or older.
  - The “85%ile” driver will be someone over age 65.

Source: FHWA
CV/AV Drivers
What Geometrics May be Influenced?

10 Controlling Criteria
- Design Speed
- Lane Width
- Shoulder Width
- Horizontal Curve Radius
- Superelevation Rate
- Maximum Grade
- Stopping Sight Distance
- Cross Slope
- Vertical Clearance
- Design Loading Structural Capacity

Roadside Safety (shy distances, clear zones)
AV / CV Vehicles

Think about this.

• Does it make a difference if the AV/CV vehicles are in mixed use traffic (with traditional vehicles)?
• What about if the AV/CV vehicles are separated from traditional vehicles?
• What if we only have AV vehicles?
Autonomous Vehicles

Or what about type of roadway?

- High Speed
- Urban

Source US DOT, transportation.gov
So, what do we think? What geometrics may be influenced?

- 10 Controlling Criteria
  - Design Speed
  - Lane Width
  - Shoulder Width
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- Roadside Safety (shy distances, clear zones)
Stopping Sight Distance (SSD)

Distance required to perceive an object in roadway and bring the vehicle to a stop

“… the sight distance at every point along a roadway should be at least that needed for a below-average driver or vehicle to stop.”

AASHTO Green Book Chapter 3

Source: FHWA
How would Stopping Sight Distance (SSD) Impact Geometrics?

- Objects offset along road
  - Bridge Abutments
  - Median Barriers
  - Crash Walls
  - Parapets
- Road itself
  - Crest Curves
  - Sag curves in conjunction with overhead structures
- Distance / Headway between vehicles
  - Intersection storage and turn bay lengths
- Intersection Sight Distance
Sight Lines

Source: AASHTO Green Book

Source: Hanson Professional Services
Stopping Sight Distance

$$SSD = 1.47 \ Vt + 1.075 \frac{V^2}{a}$$

where:

- $SSD$ = stopping sight distance, ft
- $V$ = design speed, mph
- $t$ = brake reaction time, 2.5 s
- $a$ = deceleration rate, ft/s²

Source: AASHTO 2011 “Green Book” and IDOT BDE
Road User Characteristics
Brake Reaction (Perception/Reaction) Time (t)

- Expected vs Unexpected
  - Unexpected event may add 0.5 to 2.5 seconds
- AASHTO recommends 2.5 seconds for brake reaction
- Brake Reaction Time increases with
  - Age
  - Fatigue
  - Complexity of the task
  - Physical impairments
  - Presence of Alcohol and Drugs
- Alcohol and drugs are a factor in an overwhelming proportion of traffic accidents and fatalities
**Stopping Sight Distance**

- What happens if we reduce \( t \) to 1 second?
- What happens if we reduce \( t \) to 0.3 second?

### SSD on Level Roadway

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</table>
**Stopping Sight Distance**

What happens if we increase deceleration rate to $14.8\frac{ft}{s^2}$?

### SSD on Level Roadway

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<th>SSD Calculated (a=11.2 ft/s$^2$)</th>
<th>$t$ (Seconds)</th>
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</table>
How that may impact geometrics

- HSO
- Vertical Curves

Source FHWA
Horizontal Sight Offset (HSO)

- Eye height
- Object height

Lane and Shoulder widths

- Vehicle Widths from AASHTO Green Book
  - Passenger Cars 7.0 feet
  - Buses and Trucks 8.0 to 8.5 feet

- Perhaps we can have narrower lanes as the more standard design width?
  - Save pavement
  - Possibly have more lanes in same amount of space we had before
  - Will likely need to evaluate lane widening in curves more closely due to vehicle turning paths and vehicle overhangs

Lane and Shoulder widths

- In urban and residential areas:
  - Would parking needs be reduced?
  - Would many driveways be eliminated?
For mixed use facilities that have dedicated CV and AV lanes, how much buffer might we need?

Lane and Shoulder Widths

- Do we need shoulders?
- Perhaps at strategic intervals for break downs?
- If it rains, will the vehicles automatically stay out of the lanes that have no shoulders and water is known to spread into the lanes?

Other thoughts

- Will we still need roadside safety devices?
  - Guardrail?
  - Attenuators?
  - Cable median barrier?
  - Concrete barrier?
  - Will the vehicles leave the traveled way?
    What would cause them to leave?

- Will we still have shy line offsets to abutments and other fixed objects?

- Will there be new requirements for signs and stripes?

More thoughts

- If we don’t need roadside safety devices, can we build steeper unprotected side slopes?
- Will vehicles accelerate and decelerate more efficiently by sensing all other vehicles in the vicinity?
  - Allowing for steeper grades
  - Shorter ramp terminals
  - Shorter merge areas
  - Smaller gap acceptance for turning and crossing vehicles
  - Shorter queues and shorter turn bays

Final Thoughts

- How will Construction Work Zones be impacted by AV/CV?
- Is it likely that all vehicles will go to AV?
  - Construction
  - Maintenance
    • Snow plows
    • Striping
    • Patching/filling pot holes
  - Emergency (fire, ambulance, police)
  - Others
    • Garbage trucks
    • Buses
What’s Next?

**Proactive**
- Dialogue with Vehicle Manufacturers and the AV teams
- Do they need something we might provide?
- Evaluate all the geometric elements.
- Engineers need to be ready.
- Suggestions to policies and laws

**Reactive**
Thank You!

Questions?

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