Truck Efficiency Improvements Using V2V and I2V Cooperation

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Potential Efficiency Improvements

- Platooning and cooperative adaptive cruise control (CACC)
  - Aerodynamic drag reductions (drafting)
  - Smoother traffic flow dynamics
- Freight signal priority
- Eco-signal control
Truck Platooning History

• 1996-2004: CHAUFFEUR Project analyses and tests (DaimlerBenz trucking, for EU)
• 1996-7: National Automated Highway System Consortium analyses of capacity
• 2001 - 03: PATH 2-truck platoon tests
• 2005 - 09: KONVOI Project (Germany) – 4-truck platoon tests
• 2008 – 13: Energy ITS Program (Japan) – 4-truck platoon tests
• 2009-12: SARTRE Project mixed truck/car platoon tests (Volvo, for EU)
• 2010-11: PATH 3-truck platoon tests
• 201x: Peloton commercializing 2-truck platoon
Motivations for Running Truck Platoons

• Significant reductions in energy consumption by reducing aerodynamic drag
  – Minimum 5% saving by lead truck
  – Followers saved 15% in preliminary tests, could potentially reach 25%

• Relief of driver workload and stress, helping morale and driver retention

• Significant increase in capacity per lane (trucks per hour), reducing congestion delays
  – Serve heavy demand with fewer lanes
Truck Platoon Capacity Estimates

- NAHSC studies (1997)
2-Truck Platoon Tests (3, 4 and 6 m gaps)
Aerodynamics of Class-8 Tractor-Trailer Trucks

• PATH research led by Prof. Fred Browand, USC
• Scale-model tests in wind tunnel, then full-scale tests on track, directly measuring fuel use
• Measuring effects on aerodynamic drag of:
  – Separation between trucks (primary purpose)
  – Cross-wind components
  – Tractor-trailer spacing
• Strong effects seen on separation between trucks and on shape of front of truck
Wind-Tunnel Truck Models

- Note blunt front comparable to cab-over-engine design tractor
Contrast in Gaps for Truck Tractors

Cab-over-engine (European units could be only 2 m long)

Engine-forward with Sleeper cab – Typical in U.S.
Comparison of Wind Tunnel and Direct Measurements of Fuel Saved

- **Trail Truck, Projected from Wind Tunnel Drag**
- **Lead Truck, Projected from Wind Tunnel Drag**
- **Trail Truck, Present Field Data**
- **Lead Truck, Present Field Data**

Graph showing fuel saving in tandem (% isolation value) versus truck separation (m):}

- Y-axis: Fuel Saving in Tandem (% Isolation Value)
- X-axis: Truck Separation, m
Three-Truck Automated Platoon

- Experimental implementation using 5.9 GHz DSRC for V2V communication in 2010-11, under FHWA Exploratory Advanced Research Program (EARP)
  - Gaps from 10 m to 4 m
  - Platoon join and split maneuvers
  - Variations in speed and road grade
  - Fuel consumption measurements
- Longitudinal control automated, but steering was still manual
- 8-km section of 2-lane highway, temporarily closed to public traffic for tests
- Accurate vehicle following – RMS gap variations of 22 cm for second truck and 25 cm for third truck
Three-truck Automated Platoon (2010)
Partial Automation for Truck Platooning

• Cooperative ACC for 3 tractor-trailer trucks, adding DSRC to their production ACC systems
• FHWA EARP Project team:
  – California Department of Transportation (Caltrans)
  – University of California PATH Program
  – Volvo Technology Americas
  – Cambridge Systematics, Inc.
  – Los Angeles Metropolitan Transportation Agency (LA Metro)
  – Gateway Cities Council of Governments (COG)
  – Peloton Technology (unfunded)
• October 2013 – December 2016
PATP Project Goals

• Identify market/deployment opportunities for heavy truck CACC based on industry and agency needs
• Show near-term opportunities to gain energy saving benefits from truck CACC, with modest modifications to production ACC
• Combine U.S. and European truck platoon expertise (Volvo/SARTRE and PATH) to synthesize best from both
• Work with local stakeholders on deployment strategies for truck lanes along I-710 (Los Angeles/Long Beach port)
• Test truck driver acceptance of shorter CACC following gaps while they do steering
• Measure energy savings at gaps chosen by drivers and provide results to stakeholders
• Demonstrate truck platooning for stakeholders
At Signalized Intersections

- Lower speeds than highways, so aerodynamic drafting is not a large benefit
- Capacity limited by start-up transient at red-to-green transition, not by vehicle following gap, so emphasize coordinated start to increase effective capacity and reduce delays
  - I2V broadcast of signal phase change to all queued trucks simultaneously
  - V2V coordination between trucks enables them to “follow the leader” with negligible lag
Truck Start-up from Stop

- Under-powered heavy trucks are slow to start up
- Test data shows example of 16 s to reach 20 mph (32 km/h)
  44 s to reach 40 mph (64 km/h)
- Response lag for successive trucks under driver control could be 1 – 2 s based on perception/response time plus additional time based on difficulty of perceiving speed difference.
Other I2V/V2I Opportunities for Trucks at Signalized Intersections

- Receiving real-time I2V signal phase and timing information:
  - Eco-driving profiles to minimize stopping and maximize coasting opportunities at individual intersection or along a corridor
  - Minimizing truck stopping reduces start-up delays for all the other traffic behind the trucks and reduces pavement wear
  - Eliminating dilemma zones by providing advance information on yellow transition

- V2I truck signal priority request avoids splitting truck platoons (even informal ones) and also helps reduce frequency and severity of stopping