Partially Automated Truck Platoon Field Tests for Maneuvers and Fuel Economy

X. Y. Lu, and S. E. Shladover, California PATH Program, U. C. Berkeley
B. McAuliffe, National Research Council of Canada; B. Pekilis, Transport Canada
S. Bergquist and A. Kailas, Volvo Group
M. Hanson, California Department of Transportation, O. Altan, Federal Highway Administration

Background

- Funded under Federal Highway Administration (FHWA) Exploratory Advanced Research Program solicitation, Spring 2013
- Cooperative Adaptive Cruise Control (CACC) with V2V to achieve:
  - 2-way DSRC communication among three trucks
  - Front radar and video camera fusion for target detection and tracking
  - Shorter following distances
  - For progressive market penetration of automated vehicles
  - Enhanced string stability and safety
  - Increased traffic throughput, while reducing fuel use and emissions
- Adaptive Cruise Control (ACC) cannot achieve those objectives due to cumulative delays from downstream to upstream in the string

Integrated ACC & CACC and Field Tests

- ACC for leader vehicle, or vehicle has a cut-in in the front – dynamic interaction with other traffic
- CACC - for all the following vehicles if there is no cut-in
- Cut-in and Cutout Handling: Very important scenarios for driving a partially automated vehicle in public traffic; Determine multi-vehicle cut-in with GPS distance as ground truth
  - Cut-in: transition to ACC mode
  - Cut-out transition to CACC mode
- Having tested all scenarios on multiple freeway corridors in public traffic; road geometry including grading up/down hills

Fuel Economy Test

- Fuel tank weighing after each test run
- Fuel consumption recorded automatically
- Trailer aerodynamic treatment with boat tail and side skirt

Aerodynamic Effects in Truck Platooning

As vehicles approach, they influence the flow-field around each other

- Low-speed air-wake of lead vehicle influences trailing vehicle
  (lower airspeed = lower drag)
- High-pressure zone in front of trailing vehicle influences lead vehicle
  (pushes on the front vehicle)

Test Scenarios

- Fuel consumption measurements based on SAE J1321
- Time Gap (T-Gap): 1.5s, 1.2s, 0.9s, 0.6s
- Standard trailer vs. aerodynamic trailer; with/without ballast (rolling resistance)
- Weight 65,000 lbs & 29,000 lbs
- Constant speed: 65mph vs. 55mph

Test Procedures and Fuel Econ Analysis

- Synchronized operation of 3 trucks using CACC
- A control truck at the same speed followed 2 miles behind (as baseline for variations in ambient conditions)
- Single truck constant speed reference runs, 4 trucks drove 1 mile apart
- Weighed auxiliary fuel tanks of all trucks after each run (64 miles)
Each condition repeated at least 3 times to produce average fuel consumption estimates

Fuel Economy Test

- Fuel tank weighing after each test run
- Fuel consumption recorded automatically
- Trailer aerodynamic treatment with boat tail and side skirt

Test Scenarios

- Fuel consumption measurements based on SAE J1321
- Time Gap (T-Gap): 1.5s, 1.2s, 0.9s, 0.6s
- Standard trailer vs. aerodynamic trailer; with/without ballast (rolling resistance)
- Weight 65,000 lbs & 29,000 lbs
- Constant speed: 65mph vs. 55mph

Test Procedures and Fuel Econ Analysis

- Synchronized operation of 3 trucks using CACC
- A control truck at the same speed followed 2 miles behind (as baseline for variations in ambient conditions)
- Single truck constant speed reference runs, 4 trucks drove 1 mile apart
- Weighed auxiliary fuel tanks of all trucks after each run (64 miles)
Each condition repeated at least 3 times to produce average fuel consumption estimates

Test Results

- PATH analysis results for comparison of Average Fuel Rate only based on J-1939 Bus fuel rate data, which may not as accurate as fuel tank weighing:
  Ave Fuel Rate = Cumulative fuel Consumption
  Cumulative Distance

Fig. 1 Sensor Detection & Communication Scheme
Fig. 2 Driver Vehicle Interface and Test Results
Fig. 3 PMG Test track; trailer aerodynamic treatment; tank weighing; tank weighing and data logging;
Fig. 4 Aerodynamic effect closely following truck string
Fig. 5 NRC of Canada Test Results
Fig. 6 PATH analysis results