

Effect of Wide-Based Single Tires on Class-8 Combination Truck Fuel Efficiency

Oscar Franzese
Oak Ridge National Laboratory

Helmut E. (Bill) Knee
Oak Ridge National Laboratory

Lee Slezak
U.S. Department of Energy

TRB 89th Annual Meeting
January 12th, 2010 - Washington, DC



Project Objectives

- To support modeling of heavy-truck performance and technology evaluation efforts for energy efficiency
- To provide a means of accounting for real-world driving performance within heavy-truck research and analyses
- To support truck modeling within the Powertrain Systems Analysis Toolkit (PSAT) with Class-8 data and information

Participating Vehicles



2005 Volvo

| Veh. | Transmission | Tires |
|------|--------------|-------|
| 1 | Manual | WBSs |
| 2 | Manual | Ds |
| 3 | Auto-Shift | WBSs |
| 4 | Manual | Ds |
| 5 | Auto-Shift | WBSs |
| 6 | Auto-Shift | Ds |

The Equipment



J1939 Vehicle Data Bus



Data Channels

| Signal | Signal |
|---|--|
| Instantaneous Fuel Economy | Cruise Control Set Switch |
| Average Fuel Economy | Battery Electrical Potential (Voltage) |
| Fuel Rate | Tractor Drive Axles Weight |
| Total Fuel Used | Tractor Steer Axle Weight |
| Total Idle Fuel Used | Trailer Weight |
| Current Gear | Tractor Serial Number |
| Selected Gear | Trailer Serial Number |
| Output Shaft Speed | Latitude |
| Actual Engine - Percent Torque | Longitude |
| Actual Gear Ratio | Altitude |
| Driver's Demand Engine - Percent Torque | Vertical Velocity |
| Percent Load at Current Speed | Velocity over Ground |
| Engine Speed | Longitudinal Acceleration |
| Engine Oil Temperature | Lateral Acceleration |
| Fuel Temperature | Heading |
| Front Axle Speed | Satellites |
| High Resolution Total Vehicle Distance | Time UTC |
| Accelerator Pedal Position | Wind Speed |
| Total Idle Hours | Wind Direction |
| Maximum Vehicle Speed Limit | Rain Intensity |
| Total Power Takeoff Hours | Barometric Pressure |
| Clutch Switch | Air Temperature |
| Brake Switch | Relative Humidity |
| Cruise Control Enable Switch | Tire Flag |
| Cruise Control Active | Road Grade |
| Cruise Control Accelerate Switch | Stationary Latitude |
| Cruise Control Resume Switch | Stationary Longitude |
| Cruise Control Coast Switch | Tractor-Trailer Marriage |

| |
|----------------------------|
| Fuel Rate |
| Engine Speed |
| Front Axle Speed |
| Tractor Drive Axles Weight |
| Tractor Steer Axle Weight |
| Trailer Weight |
| Latitude |
| Longitude |
| Altitude |

Superimposed Trips



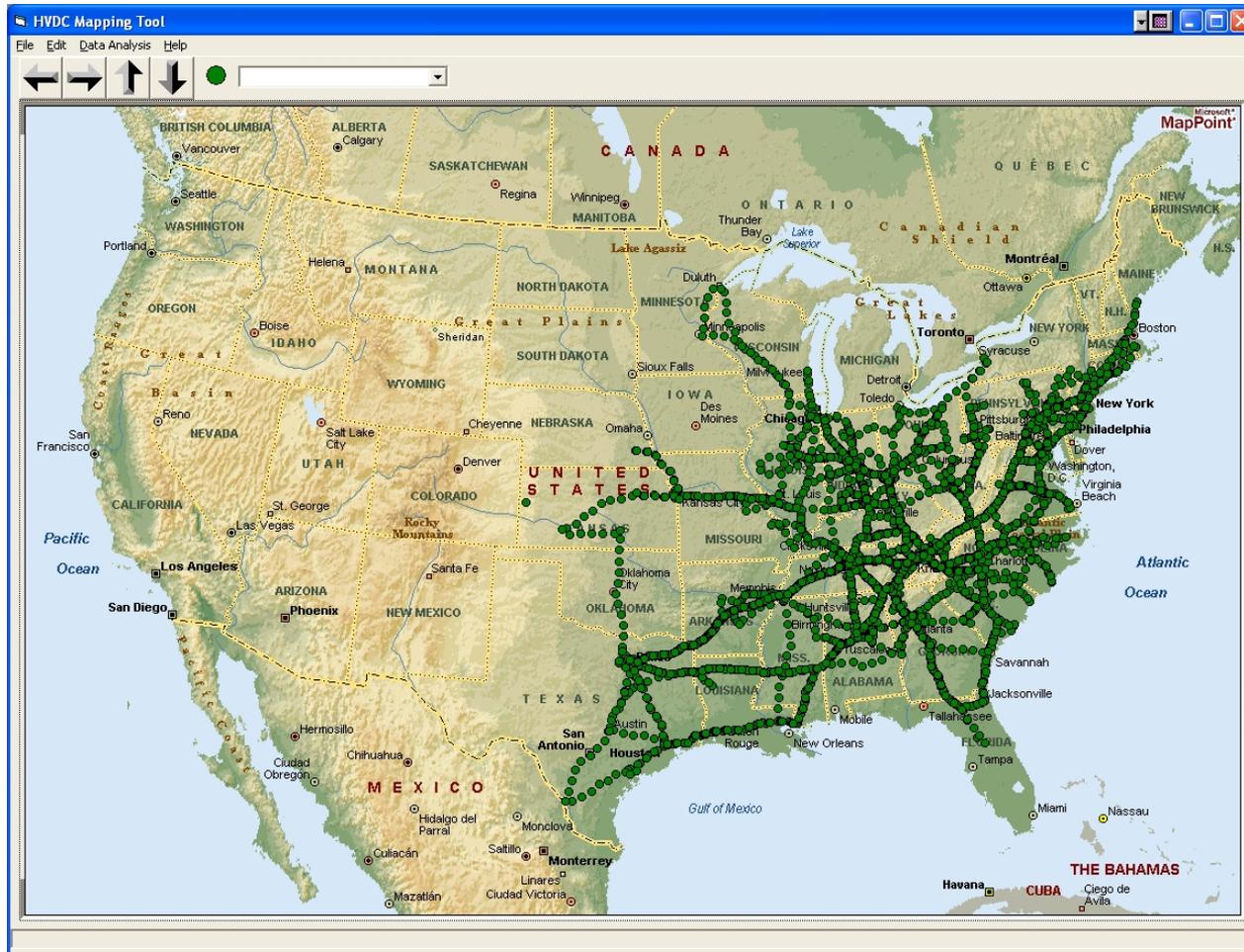
General Statistics

| | Vehicle (Transmission-Tires) | | | | | | Grand Total |
|-------------------------|------------------------------|--|---------|---------|---------|--------------|-------------|
| | 1 (M-S) | 2 (M-D) | 3 (A-S) | 4 (M-D) | 5 (A-S) | 6 (A-D) | |
| Dist. Traveled [m] | 106,891 | 114,095 | 117,355 | 124,917 | 127,626 | 97,417 | 688,302 |
| Total Time [hr] | 10,689 | 11,410 | 11,736 | 12,492 | 12,763 | 9,742 | 73,825 |
| Avg. Speed [mph] | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 9.3 |
| Avg. Mov. Sp [mph] | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 9.3 |
| Total Fuel [gal] | 15,982 | 16,701 | 16,805 | 19,361 | 18,494 | 15,995 | 103,336 |
| Overall Fuel Eff* [mpg] | 6.69 | 6.83 | 6.98 | 6.45 | 6.90 | 6.09 | 6.66 |
| | | Fuel Efficiency [mpg] | | | | | |
| | | Tractor with WBS/Trailer (any) | | | | 6.86 | |
| | | Tractor with Duals/Trailer (any) | | | | 6.46 | |
| | | Percent Difference (WBSs vs. Duals) | | | | 6.17% | |

*From Vehicle's Databus – Instantaneous Fuel Consumption

Fuel Efficiency Comparison (cont.)

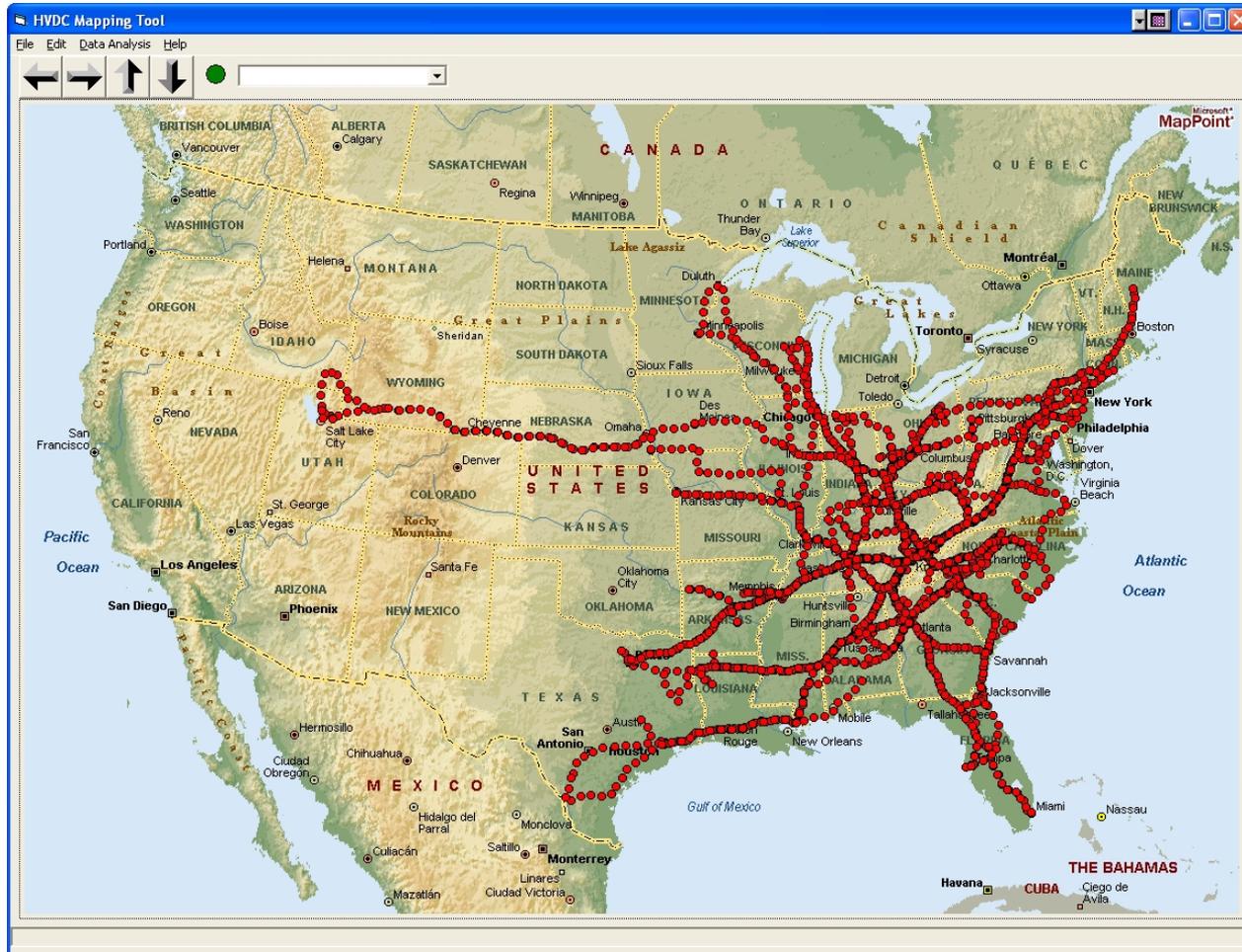
Tractor w/Duals and Trailer w/Duals



Avg. Fuel Efficiency (1,798 100-mile segments): 6.60 mpg

Fuel Efficiency Comparison (cont.)

Tractor w/WBSs and Trailer w/WBSs



Avg. Fuel Efficiency (871 100-mile segments): 7.23 mpg

Fuel Efficiency Comparison (cont.)

| | Tractor-Trailer Tire Configuration | | | |
|----------------------------------|------------------------------------|---------|---------|-----------|
| | Ds-Ds | Ds-WBSs | WBSs-Ds | WBSs-WBSs |
| Sample Average FE | 6.60 | 7.00 | 7.03 | 7.22 |
| Sample Std. Dev. | 1.21 | 1.32 | 1.19 | 1.19 |
| Sample Size | 1,798 | 850 | 1,956 | 871 |
| Mean of Difference With D-D | | 0.40 | 0.42 | 0.61 |
| Std. Dev. of Difference With D-D | | 0.05 | 0.04 | 0.05 |
| Test Statistic Value (Z) | | 7.41 | 10.77 | 12.43 |
| Reject Ho at Confidence Level | | 99.99% | 99.99% | 99.99% |

Fuel Efficiency Comparison (cont.)

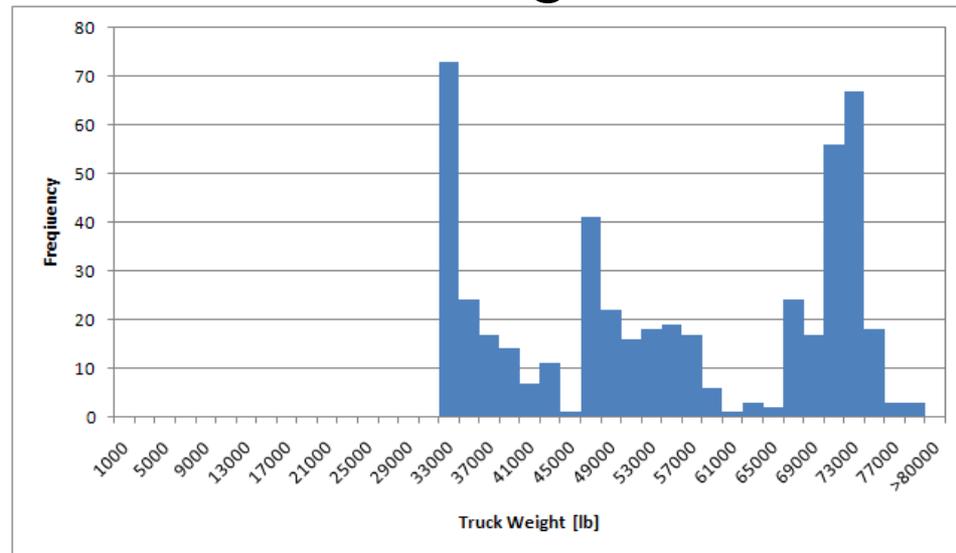
| Tractor-Trailer Tire Configuration | Distance Traveled [miles] | Average FE [mpg] | Percent Diff in FE with Duals-Duals [%] |
|------------------------------------|---------------------------|------------------|---|
| WBSs-WBSs | 87,002 | 7.22 | 9.9 |
| WBSs-Ds | 190,503 | 7.03 | 6.4 |
| Ds-WBSs | 85,002 | 7.00 | 6.0 |
| Ds-Ds | 179,503 | 6.60 | |

Fuel Efficiency Comparison: Effect of Tires

- For every case in which WBS tires were used, fuel efficiency improved over the all-duals case
- Improvements of nearly 10% for all-WBS tires were seen as compared to all-duals
- Improvements were statistically significant

Fuel Efficiency: Tires and Payload

- Tractor Only (No Trailer)
- Light Load - Vehicle Weight: 24,000-44,000lbs
- Medium Load - Vehicle Weight: 44,000-62,000lbs
- Heavy Load - Vehicle Weight: 62,000-80,000lbs



Fuel Efficiency: Tires and Payload (cont)

| Tractor-Trailer Tire Configuration | Load Level | | | | | | | |
|--|------------------|-------------------|------------------|-------------------|------------------|-------------------|------------------|-------------------|
| | Tractor Only | | Light Load | | Medium Load | | Heavy Load | |
| | Avg. FE [mpg] | % Diff w/Ds-Ds |
| Ds-Ds | 9.01 | | 8.07 | | 7.17 | | 6.24 | |
| Ds-WBSs | NA | NA | 8.61 | 6.8 | 7.48 | 4.3 | 6.50 | 4.2 |
| WBSs-Ds | NA | NA | 8.63 | 7.1 | 7.51 | 4.8 | 6.56 | 5.2 |
| WBSs-WBSs | 10.52 | 16.8 | 8.79 | 8.9 | 7.93 | 10.6 | 6.88 | 10.2 |

Distributions of Time Spent and Fuel Consumed while Idling

| Idling Interval [min] | Number of Incidences | Time | | | Fuel | | |
|-----------------------|----------------------|---------------|---------------------|--------------|--------------|---------------------|--------------|
| | | [hrs] | % Total Idling Time | % Total Time | [gal] | % Total Idling Fuel | % Total Fuel |
| 0-5 | 53,269 (0.7) | 664 | 5.6 | 2.8 | 371 | 5.2 | 0.4 |
| 5-15 | 5,310 (9.0) | 784 | 6.6 | 3.3 | 398 | 5.6 | 0.4 |
| 15-60 | 3,085 (29.0) | 1,479 | 12.5 | 6.2 | 1,454 | 20.4 | 1.4 |
| 60-120 | 767 (83.5) | 1,067 | 9.0 | 4.5 | 570 | 8.0 | 0.6 |
| 120-180 | 384 (149.2) | 947 | 8.0 | 4.0 | 525 | 7.4 | 0.5 |
| 180-240 | 287 (211.6) | 980 | 8.3 | 4.1 | 539 | 7.6 | 0.5 |
| 240+ | 939 (371.6) | 5,874 | 49.8 | 24.7 | 3,269 | 45.9 | 3.2 |
| TOTAL | | 11,795 | 100.0 | | 7,125 | 100.0 | |

Summary

- Six Class-8 trucks logged more than 700,000 miles collecting 60 channels of information at 5Hz
- Statistically significant improvement in fuel efficiency with respect to the base case (duals-duals) when WBS tires are involved
 - 6% to 9% fuel efficiency improvements (all trips, any payload)
 - 4% to 10% fuel efficiency improvements (all trips, light payload, medium payload, heavy payload)

Contact Information

Dr. Oscar Franzese

Oak Ridge National Laboratory

franzeseo@ornl.gov

(865) 946-1304