International Vehicle Productivity Performance Benchmarking

Workshop
OECD-ITF International Study on Truck Safety, Productivity, and Sustainability

Transportation Research Board 89th Annual Meeting
Washington DC
10 January 2010

John Woodroofe
University of Michigan Transportation Research Institute

Paul Nordengen
Council for Scientific and Industrial Research (CSIR) South Africa
Credits and Co-Authors

- Klaus-Peter Glaeser – Federal Highway Research Institute (BASt) Germany
- Paul Nordengen – Council for Scientific and Industrial Research (CSIR) South Africa
Purpose of Benchmarking Study

To compare the most common trucks “workhorses” from participating countries as well as various high and very capacity vehicles in terms of:

– Road wear performance
– Impact on road structures
– Safety performance (with a focus on vehicle design)
– Productivity (in terms of mass and volume)
– Environmental impacts (emissions, energy consumption)
Increasing truck volumes vs productivity
Essential Aspects of Truck Transport

- Large trucks exist to do work and to do it efficiently. Their worth and function are tied directly to work performance in exchange for money – there is a large incentive to be efficient.
- Freight tasks vary, as do the weight, shape and density of cargo transported, therefore vehicle efficiency varies for a given cargo and vehicle design.
Essential Aspects of Truck Transport

- The nature of freight transport can be volume limited or mass limited. Transport efficiency for volume limited freight task is evaluated differently than mass limited freight task.

- A specific vehicle with a low fuel consumption does not necessarily have good fuel efficiency. In the context of this study:
  - Fuel consumption references fuel used to move a vehicle.
  - Fuel efficiency refers to the fuel used to accomplish a specific freight or work task.
Regulatory Factors influencing Efficiency

- Basic aspects of truck design such as the length, wheelbase, width, height, axle loads, axle spacing and GVW, are influenced and limited by size and weight regulations.
- Since many of these factors directly influence fuel efficiency it can be concluded that fuel efficiency is directly related to size and weight regulation.
- Size and weight regulation has a significant influence on national fuel use and emissions output.
Vehicle Classification

- 40 heavy vehicles representing 10 participating countries were examined
- The study focused on Class 8 highway transport vehicles
  Note: In the U.S. class 8 vehicles consume 59% of all fuel used by commercial vehicles

Vehicle Classification
- Workhorse – common “go anywhere” vehicle
- High capacity – up to 57 tons
- Very high capacity – up to 77 tons greater than 98 ft
Productivity and Environmental Performance
Steady State Energy Balance

Total energy used per hour (90 km/h, 44 tonne, level road for one hour) 343 kWh

- Engine losses 200 kWh
- Aerodynamic Losses 53 kWh
- Rolling Resistance 65 kWh
- Drive train 10 kWh
- Auxiliary loads 15 kWh
Calculating Energy Consumption

The power required to overcome aerodynamic drag and tire rolling resistance at constant cruising speed on a level road with no wind can be expressed as follows:

\[ P = (F_R + F_A) \times v = \left( C_R \times m \times g + \frac{1}{2} \times \rho \times C_D \times A \times v_x^2 \right) \times v \]

P is the power required to overcome the resistive forces – (expressed as Watts)
F_R is the tire rolling resistive resistive force
F_A is the aerodynamic resistive force
C_R is the tire rolling resistance coefficient
C_D is the aerodynamic drag coefficient
A is the frontal area of the vehicle
v is the velocity of the vehicle
\( \rho \) is the air density
internal losses + 225 kWh applied equally to all vehicles in this analysis.
Estimating CO₂ Emissions

- Diesel fuel consumed for truck applications is approximately 200 grams/kWh (assuming 50% engine efficiency)
- Mass of diesel fuel is approximately 850 grams/litre
- Amount of CO₂ emissions produced is ~2.67 kg/litre
- Therefore the amount of CO₂ produced per kWh is 0.63 kg
Results
Optimum cargo density
(cargo mass / cargo volume)

Vehicle Density (cargo-ton/m$^3$)
Energy efficiency: cargo mass volume

(Cargo mass x cargo volume x distance / energy consumed)
Cargo mass footprint (Road occupancy)
(Available Cargo Mass / Overall Vehicle Length)
# Workhorse vehicles by country

<table>
<thead>
<tr>
<th>5-axle tractor semitrailers</th>
<th>6-axle tractor semitrailers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>South Africa</td>
</tr>
<tr>
<td>96,800 lbs</td>
<td>108,460 lbs</td>
</tr>
<tr>
<td>Mexico</td>
<td>Mexico</td>
</tr>
<tr>
<td>96,800 lbs</td>
<td>106,700 lbs</td>
</tr>
<tr>
<td>South Africa</td>
<td>Denmark</td>
</tr>
<tr>
<td>95,700 lbs</td>
<td>105,600 lbs</td>
</tr>
<tr>
<td>Europe</td>
<td>Canada</td>
</tr>
<tr>
<td>88,000 lbs</td>
<td>102,300 lbs</td>
</tr>
<tr>
<td>Canada</td>
<td>Australia</td>
</tr>
<tr>
<td>86,900 lbs</td>
<td>100,100 lbs</td>
</tr>
<tr>
<td>US</td>
<td>US (a)</td>
</tr>
<tr>
<td>80,000 lbs</td>
<td>97,000 lbs</td>
</tr>
<tr>
<td></td>
<td>UK</td>
</tr>
<tr>
<td></td>
<td>96,800 lbs</td>
</tr>
<tr>
<td></td>
<td>US (b)</td>
</tr>
<tr>
<td></td>
<td>92,000 lbs</td>
</tr>
</tbody>
</table>
Conclusions

- Truck size and weight regulations directly influence transport efficiency, fuel use and emissions output.
- Such regulations represent a tool that can not only protect the infrastructure but also encourage vehicles that provide significant societal benefits.
- From the vehicles examined in this study, it is apparent that the higher capacity vehicles in use around the world are delivering improved productivity and efficiency with greater increases in cargo volume than cargo mass.
- Higher capacity vehicles need to be managed to ensure compatibility with the infrastructure and to realise maximum safety potential.
Thank you