Towards Sustainable Road Freight

First Cambridge Workshop on Energy, Transport and Urban Infrastructure

David Cebon

Centre for Sustainable Road Freight
September, 2015

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Sustainability

Productivity? Profit?

People
Prosperity
Planet

UK’s Greenhouse Gas Emissions

- Energy industries: 33%
- Transport: 21%
- Manufacturing industries and construction: 13%
- Residential: 12%
- Agriculture: 7%
- Industrial processes: 4%
- Waste treatment and disposal: 4%
- Commercial and institutional: 3%
- Other: 3%

Source: National Atmospheric Emissions Inventory (IPCC categories) 2007
### UK’s GHG emissions from transport

**GHG Emissions from Road Transport:**
- 20% of Transport Sector
- 4-5% of UK total emissions

**Other facts for Freight and Logistics:**
- 7% of all UK jobs
- 2.3m people in 196,000 companies
- 1-3% Net Return on Investment

Source: National Atmospheric Emissions Inventory (IPCC categories) 2007

### Life without Lorries: Sustainable?

**Collapse of economic and welfare systems**

<table>
<thead>
<tr>
<th>Groceries</th>
<th>Beer</th>
<th>Fuel</th>
<th>Healthcare</th>
<th>Banking</th>
<th>Postal / parcel services</th>
<th>Waste disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td><strong>Day 2</strong></td>
<td><strong>Day 3</strong></td>
<td><strong>Day 4</strong></td>
<td><strong>Day 5</strong></td>
<td></td>
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<tr>
<td>All movements of lorries over 3.5 tonnes cease at 12am</td>
<td>Supermarket stocks of many perishable / short shelf-life product run out, including bread, milk and eggs</td>
<td>Most petrol stations run out of fuel</td>
<td>Petrol stations run dry</td>
<td>Half of the car fleet without fuel</td>
<td></td>
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<tr>
<td>Most mail services and parcel deliveries stop</td>
<td>Milk disposal on farms</td>
<td>Around 15% of the car fleet without fuel</td>
<td>Most of the manufacturing sector shut-down</td>
<td>Large proportion of the labour force laid-off or unable to travel to work</td>
<td></td>
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<tr>
<td>No newspapers</td>
<td>More manufacturing in low-inventory sectors closes down</td>
<td>Supermarket stocks of fast-moving grocery lines exhausted</td>
<td>Most non-electrified rail services suspended</td>
<td>Retail stocks of most grocery products exhausted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturers operating on a just-in-time basis suspend operations</td>
<td>Shortage of cash in banks and ATMs</td>
<td>Introduction of rationing for fuel and some food products</td>
<td>Serious cash shortages</td>
<td>Almost all manufacturing closed down</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No supplies of fresh produce in grocery outlets</td>
<td>Construction work ceases on most building sites</td>
<td>Fast food outlets close</td>
<td>Bus companies reduce off-peak frequencies, esp. in rural areas</td>
<td>Severe disruption of the health service</td>
<td></td>
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</tr>
<tr>
<td>Growth of farmers’ markets</td>
<td></td>
<td>Widespread lay-offs from manufacturing sector</td>
<td>Gas and water utilities disrupted by lack of fuel and spare parts</td>
<td>Serious problems from the accumulation of waste</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Busier pubs run out of beer</td>
<td>Congestion at ports stops off-loading of vessels</td>
<td>Range of non-food products in shops substantially depleted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slaughter of poultry on farms</td>
<td></td>
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</tbody>
</table>

McKinnon et al, 2004 (Based on data from disruptions to UK road haulage in 1979 and 2000)

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**Fuel Consumption Model**

Key Elements of Model:
- Thermodynamic efficiency (engine map)
- Air Resistance
- Rolling Resistance (tyres and drive train)
- Kinetic Energy / Braking losses

(Extensive programme of parameter measurement with instrumented vehicle for validation)
Engine Map

Model Validation

Test Data
Simulation
Overall model accuracy: 1.4% to 7.9%, (depending on test conditions)

Effects of Speed
### Simulated Vehicles

<table>
<thead>
<tr>
<th></th>
<th>GVW (t)</th>
<th>Payload (t)</th>
<th>Payload (%)</th>
<th>Power HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid</td>
<td>26</td>
<td>16</td>
<td>63</td>
<td>206</td>
</tr>
<tr>
<td>Single</td>
<td>44</td>
<td>29</td>
<td>66</td>
<td>336</td>
</tr>
<tr>
<td>B-double</td>
<td>60</td>
<td>39</td>
<td>66</td>
<td>425</td>
</tr>
<tr>
<td>A-double</td>
<td>82</td>
<td>58</td>
<td>71</td>
<td>425</td>
</tr>
</tbody>
</table>

*Unladen return journey ➔ +70% energy for 44t artic*

- Higher capacity, full vehicles are always better
- Both logistics and vehicle technology matter
Driving Cycle - 56mph, 10km

Typical Power Profile:
Tractor-semitrailer, Max speed 56mph
Effect of Congestion: Tractor-semitrailer, Max speed 56mph

- Congestion has a dominant effect on energy consumption
- Night-time curfews: 9pm-7am!

Effects of Speed

Higher energy loss at 56mph:
- Kinetic energy wasted in braking
- Aerodynamic loss due to higher average speed
Effect of Vehicle Configuration, Motorway (56mph max)

Larger trucks use significantly less fuel
- A-double is 18% more efficient than 44t artic
Energy penalty for trans-shipping onto smaller vehicles
- Rigid uses 37% more fuel than Single trailer

Benefits of Long Combination Vehicles

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Reduction due to LCVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight movements and overall truck-kms</td>
<td>44%</td>
</tr>
<tr>
<td>Overall shipping costs</td>
<td>29%</td>
</tr>
<tr>
<td>Fuel consumption / greenhouse gas emissions</td>
<td>32%</td>
</tr>
<tr>
<td>Road wear</td>
<td>40%</td>
</tr>
</tbody>
</table>

Public Opinion?

A new type of ‘mega-truck’ weighing more than a fully-laden airliner that could soon be thundering along British streets would pose an unacceptable risk to other road users, according to the Environmental Transport Association (ETA).

The 4-ton mega-trucks measure more than 25 metres in length and are heavier than 52 family cars, and at 737-300 size.

‘Monster lorry’ makers flaunt their green credentials

HANOVER, Germany (Reuters) – Truck makers at a major trade fair opening in Germany on Thursday, "monster lorries" are coming.

And to the dismay of environmentalists, makers of these new 25-metre (82-foot), 60-tonne articulated behemoths say they are a greener alternative to the shorter lorries on European roads now.

Regenerative Braking

Low Pressure Reservoir

Hydraulic Oil

Pressurized Gas

High Pressure Accumulator

Weight Comparison
Parallel Hybrids

RDS
NH4H (Battery)
NH4Cl (Battery)
SuperCap (Super Capacitor)

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Comparison of Regenerative Braking Technologies

Best performance for regenerative braking: 20% lighter, 50% smaller than best electrical system.

Insufficient storage for stop from 56mph.

Biggest energy saving is for stop-start urban (36%).

Regenerative Braking
(2 tonnes, 3.80MJ, 80%)
Technologies for reducing fuel consumption and CO2

Reduction of Greenhouse Gases

- Electrification
- Dual Fuel
- CNG/LNG
- Electric Hybrids
- Hybrid

Best solutions

Low

Medium

High

Barriers to mainstream adoption (Technical, Economic, Political)
Conclusions

1. Lorries are essential for modern living
2. For environmental reasons, they need to get bigger
3. Social change is necessary…
   - Re-timing of deliveries
   - Acceptance of larger vehicles on long-haul operations
   - Home deliveries
   - …
4. Lack of sensible public debate is highly detrimental.
Introduction to
Centre for Sustainable Road Freight

Heriot Watt University
Prof Tooraj Jamasb
Prof Alan McKinnon
Dr Andrew Palmer
Dr Maja Piecyk (PI)
Dr Guy Walker

Cambridge University
Prof Holger Babinsky
Dr Adam Boies
Prof David Cebon (PI)
Dr David Cole
Prof Nick Collings
Prof Nick Kingsbury
Dr Michael Sutcliffe

For more information contact:
Prof David Cebon: dc@eng.cam.ac.uk
Dr Maja Piecyk: m.piecyk@hw.ac.uk

Aims

1. Develop a comprehensive programme of research on the opportunities for improving the environmental sustainability of road freight transport:
   - Meet Corporate and Government emissions reduction targets for the road freight sector
   - 80% reduction in CO2 emissions due to road freight transport by 2050.
2. Develop innovative technical and operational solutions to road freight challenges
3. Tackle the environmental, economic and social issues – triple bottom line approach
4. Establish close links with all the main stakeholders in the road freight sector: a stable, long-term research collaboration
5. Help members decarbonize their operations
6. Provide policy advice
A Unique Collaboration…

Cambridge University Engineering Department
Internationally leading capability in heavy vehicle engineering

Heriot Watt University
A world leader in logistics

* Advisory Committee Member

Summary of Research Programme

Core Activities
- Future Mapping
- Maximising Impact
- Research Portfolio Management

Data Management, Scenario Analysis & Decision Support
- Driver Skills & Training
- Traffic Congestion
- Carbon for Money Tool
- Integrated Logistics Dataset

Optimising Long Haul Transport
- Reconfiguration of SC Networks
- Lightweight Trailers
- Aerodynamic Improvements
- Reduced Rolling Resistance

Sustainable Urban Freight
- Alternative Fuels
- In-cab Feedback & Driver Behaviour
- Low-energy Delivery Vehicles
- Improved Urban Logistics
- In-service Data Collection
Some Research Highlights…

- Active Trailer Steering: An enabling technology for higher capacity vehicles. IP licensed to Consortium partner.
- ‘Carbon for Money’ tool: Helping transport operators make the most effective decarbonisation decisions.
- Real-time logging of vehicle performance in-service: Fuel usage; Payload, Location, Speed; Dynamics; Safety...
- Hydraulic regenerative braking system for urban delivery vehicles.
- Task analysis for commercial driving: identification of modern and future training needs from a new perspective.

More Research Highlights...

- Measurement of vehicle underbody flows and effects of interventions.
- Aerodynamic improvements on in-service test trailer.
- Methods for characterising vehicles and measuring benefits of interventions.
- Back-haul opportunities through collaboration. Data from 10 fleets over 1 month.
- Trailer light-weighting: geometry optimisation of steel chassis beams.
The Biggest Benefits

1. Improve engine and drive-train efficiencies; reduce rolling resistance and aerodynamic resistance ➔ save up to 5%
2. Driver training ➔ save up to 10% (must be maintained)
3. Reduce unladen mass ➔ Save up to 10%
4. Reduce traffic congestion ➔ reduce fuel consumption (and CO₂) by up to 50%
   • use higher capacity vehicles for the same freight task
   • eliminate night-time curfews on freight deliveries
   • optimise traffic control
   • reduce accidents and delays from road maintenance
   • Improved vehicle routing
5. Change logistic patterns:
   • Never come home empty ➔ save up to 40%
   • Use tractor-semitrailer instead of 2 rigids ➔ save 35%
     (Trailer axle steering provides the increase in manoeuvrability needed to do this in urban areas)
   • Use longer vehicles (eg 2 trailers) ➔ save 10-20%
6. Regenerative braking (hybrids) ➔ save 25%
7. Alternative Fuels – CNG and Biogas...