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Towards Sustainable Road Freight

First Cambridge Workshop on Energy, Transport and Urban Infrastructure

David Cebon

Centre for Sustainable Road Freight

September, 2015

Contents

Sustainability

Productivity?

Profit?

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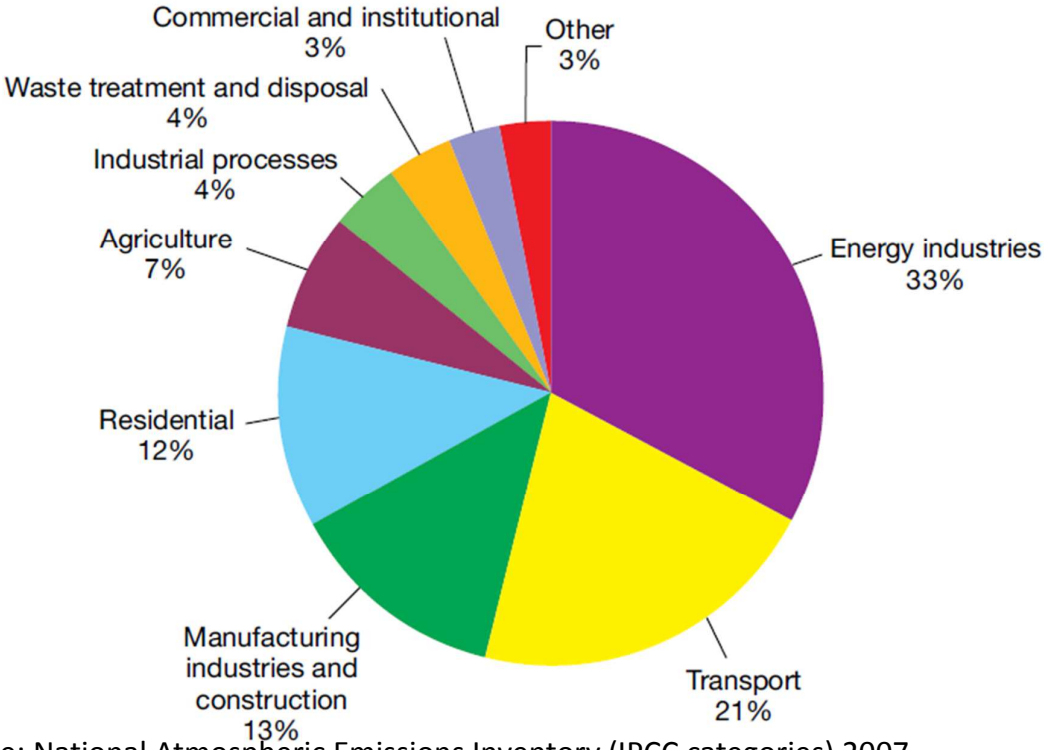
UK's Greenhouse Gas Emissions



Source: National Atmospheric Emissions Inventory (IPCC categories) 2007

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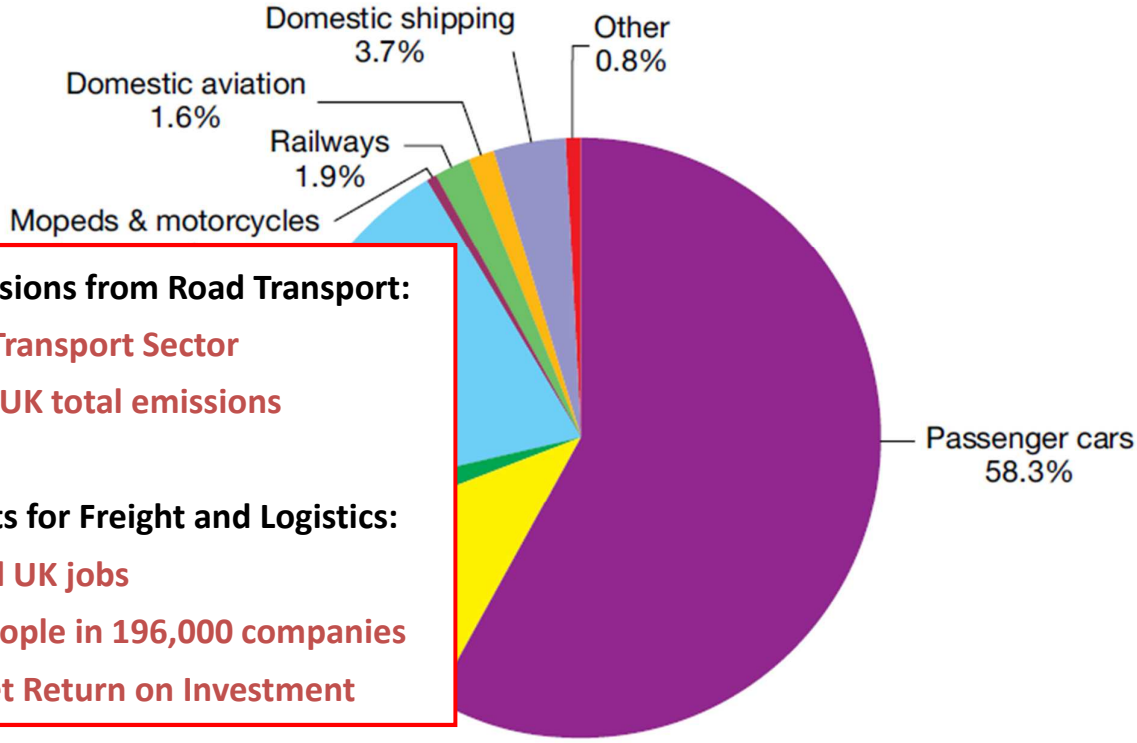
UK's GHG emissions from transport



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

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Life without Lorries: Sustainable?

Collapse of economic and welfare systems

Groceries Beer Fuel Healthcare Banking Postal / parcel services Waste disposal

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

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

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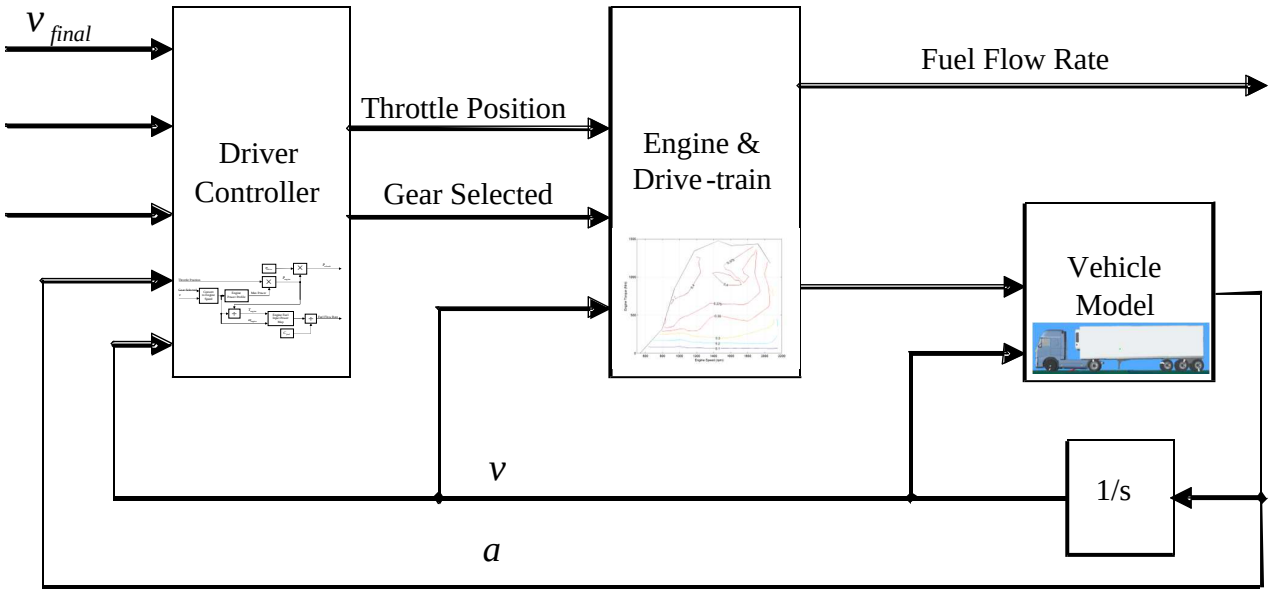
Fuel Consumption Model



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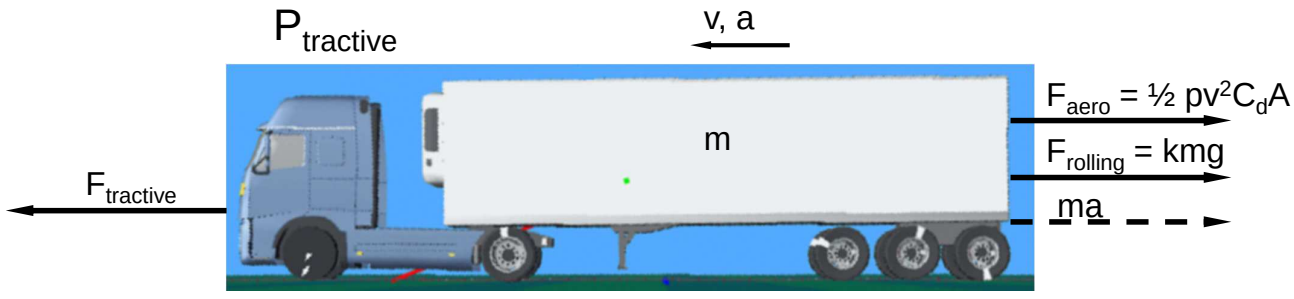
Fuel Consumption Model



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)**

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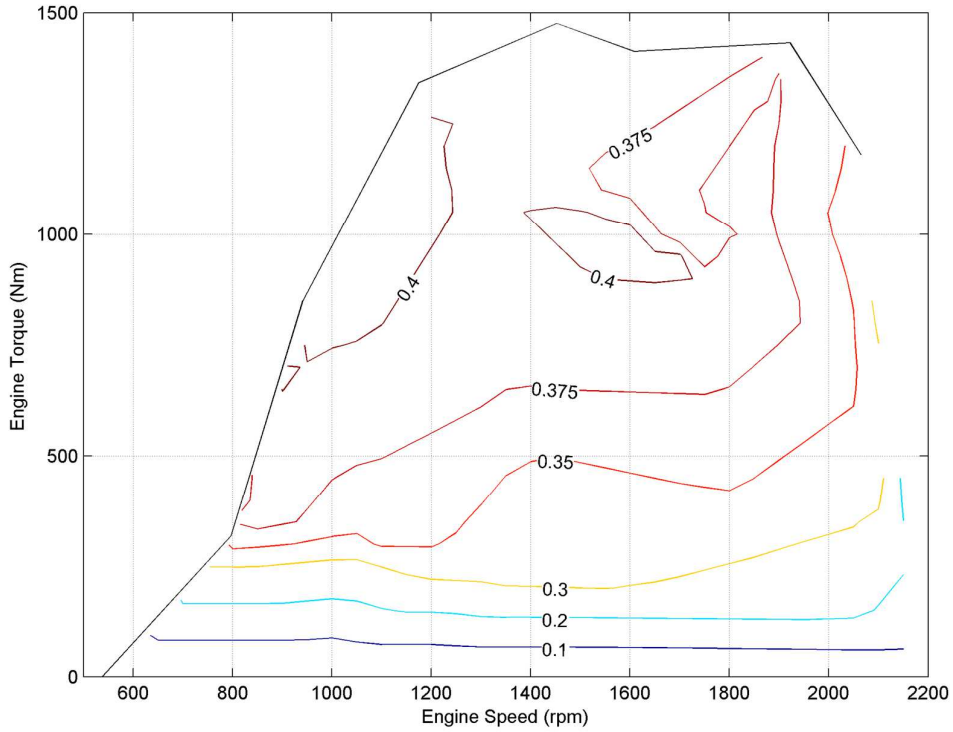
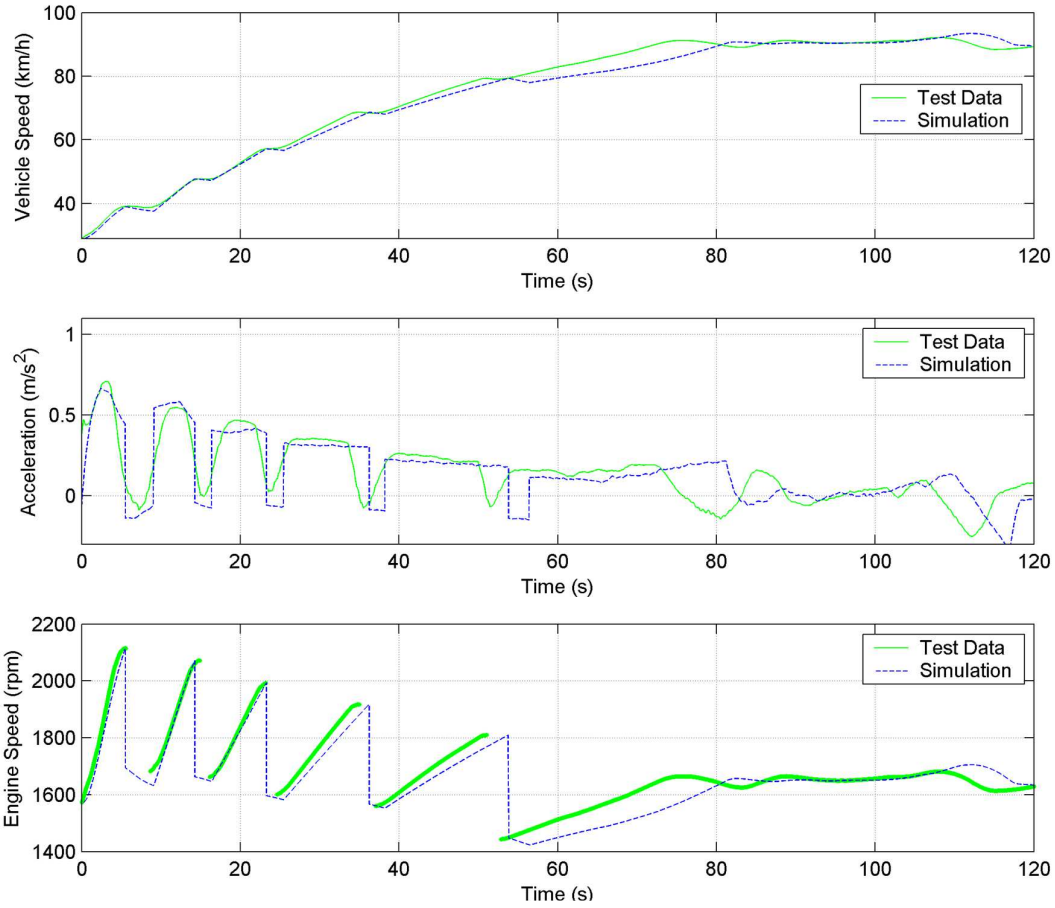
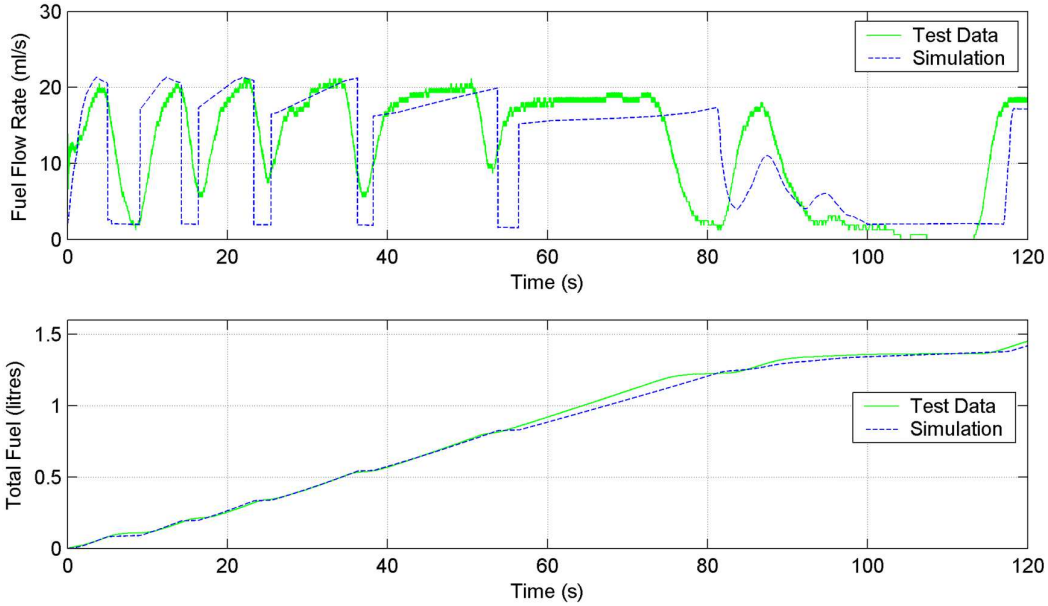
Engine Map



Model Validation



Model Validation (cont..



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

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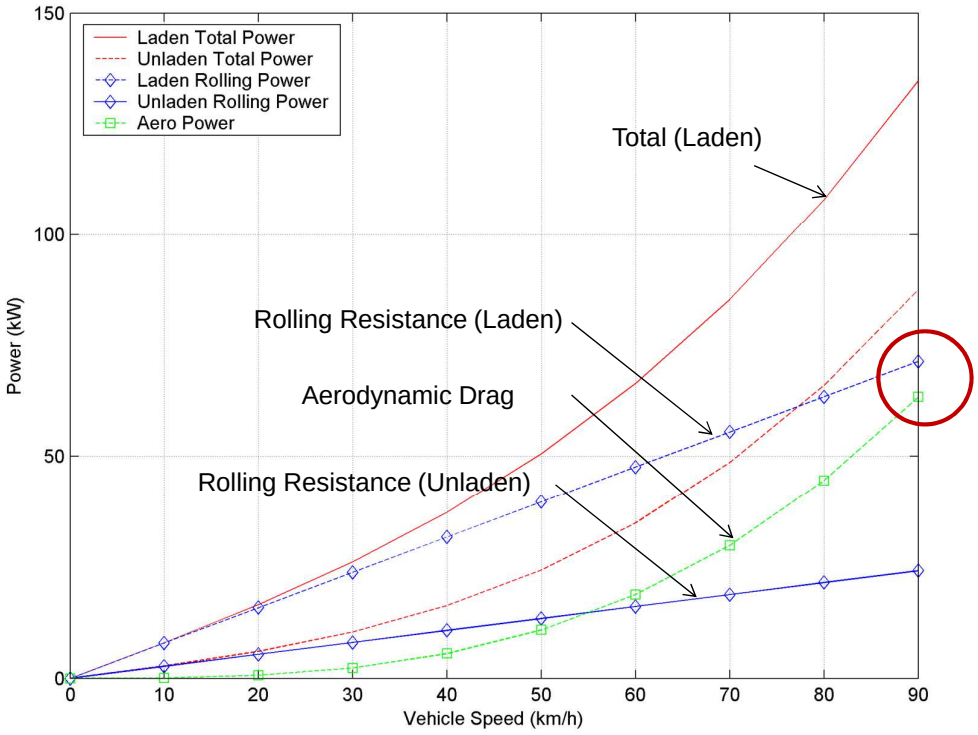
Effects of Speed



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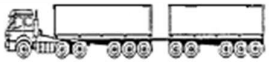
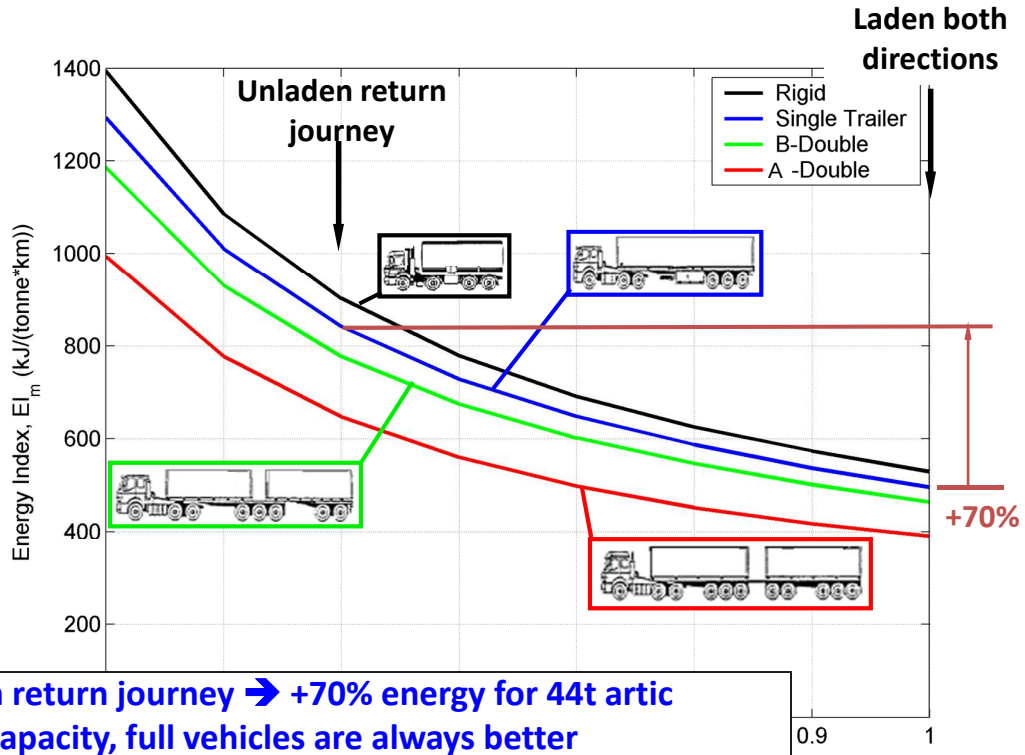
Simulated Vehicles

	GVW (t)	Payload (t)	Payload (%)	Power HP
 Rigid	26	16	63	206
 Single	44	29	66	336
 B-double	60	39	66	425
 A-double	82	58	71	425

BoM Analytics

Effect of Load Factor



- **Unladen return journey ➔ +70% energy for 44t artic**
- **Higher capacity, full vehicles are always better**
- **Both logistics and vehicle technology matter**

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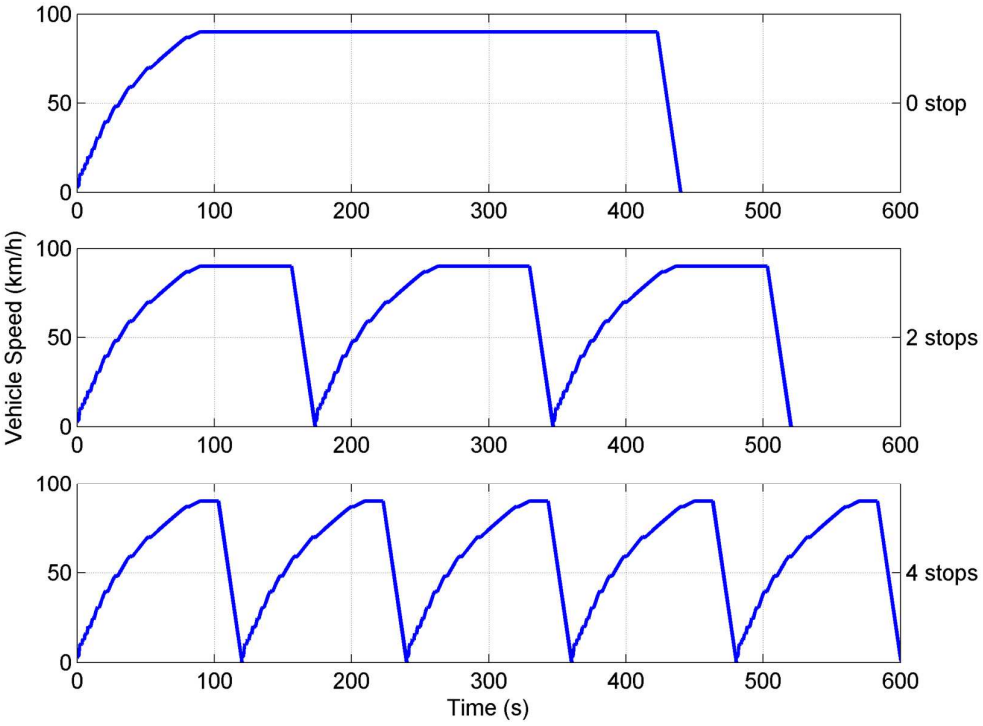
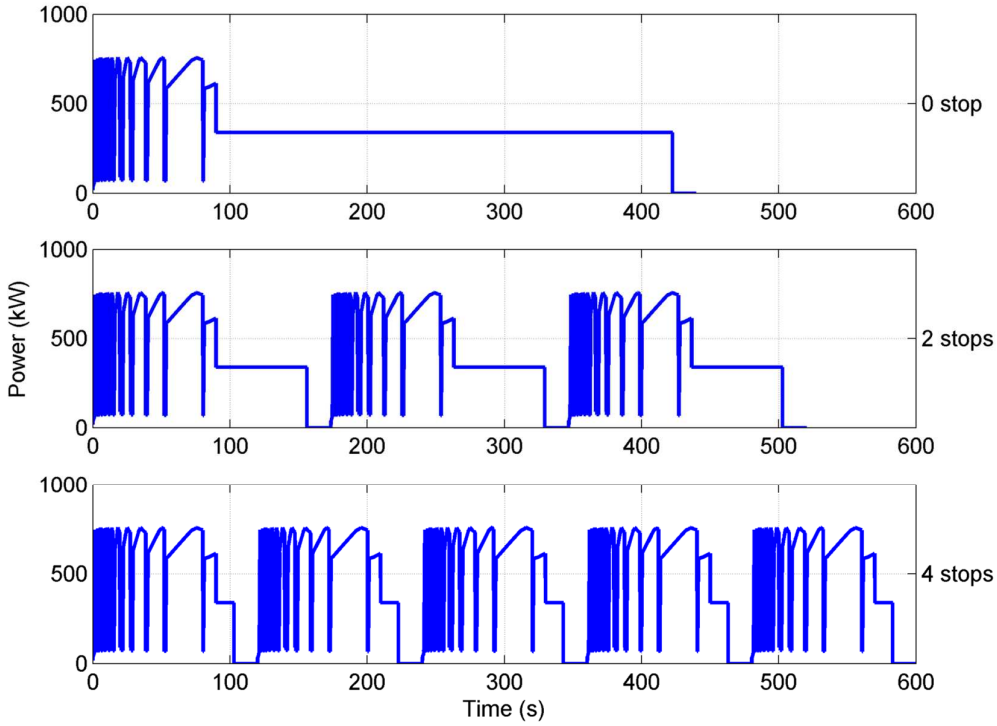
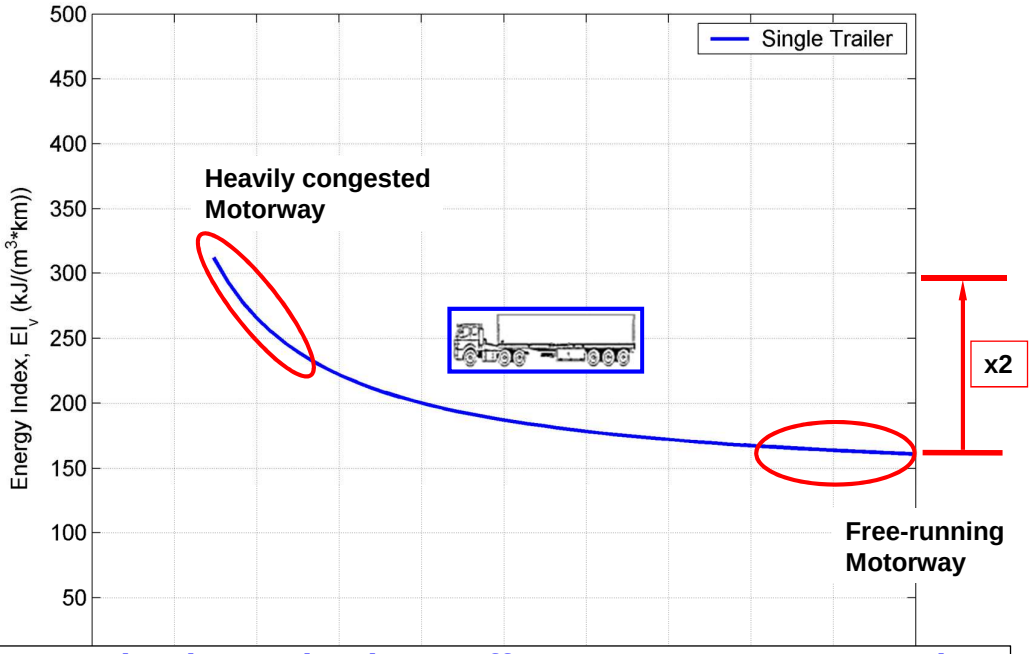
Driving Cycle - 56mph, 10km



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!**

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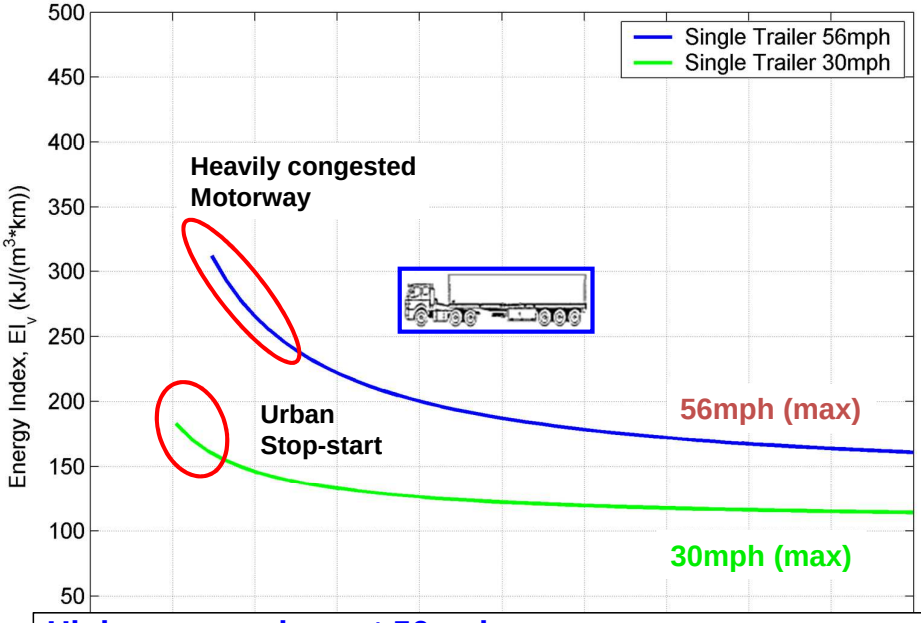
Effects of Speed



Higher energy loss at 56mph:

- **Kinetic energy wasted in braking**
- **Aerodynamic loss due to higher average speed**

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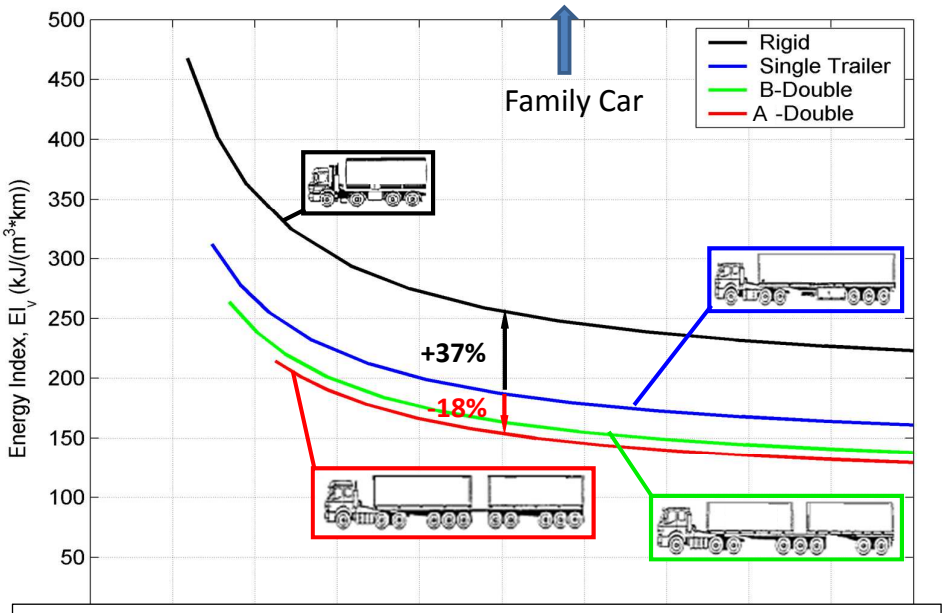
Effect of Vehicle Configuration, Motorway (56mph max)



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**

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Benefits of Long Combination Vehicles

Performance Measure	Reduction due to LCVs
Freight movements and overall truck-kms	44%
Overall shipping costs	29%
Fuel consumption / greenhouse gas emissions	32%
Road wear	40%

Source: Woodrooffe, J. and L. Ash, *Economic Efficiency of Long Combination Transport Vehicles in Alberta*. 2001

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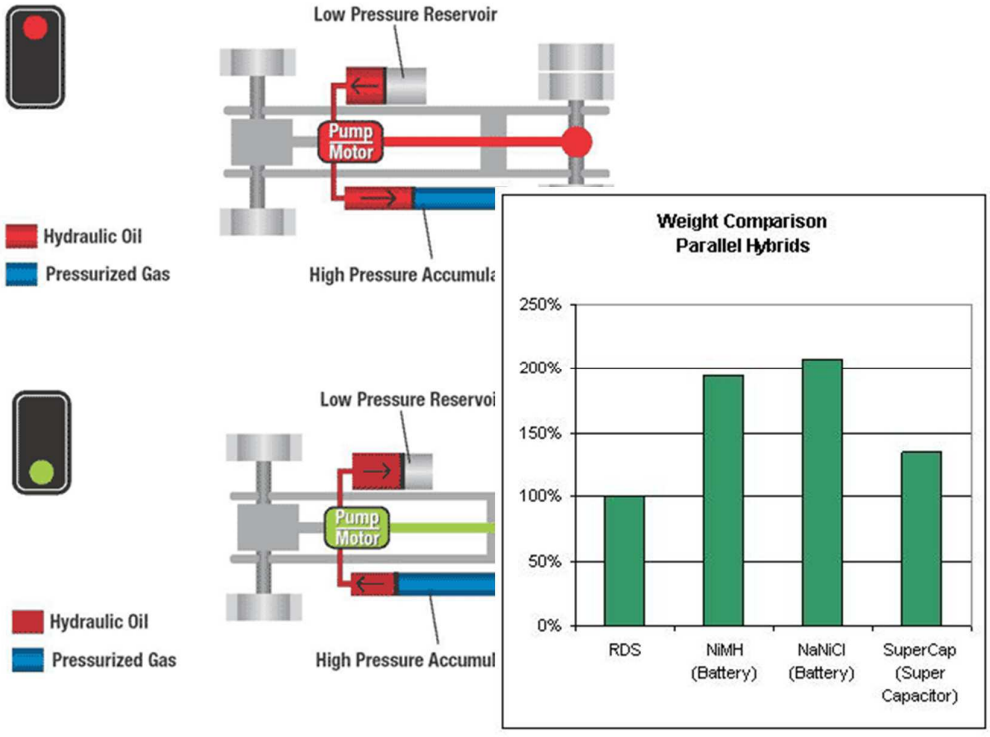
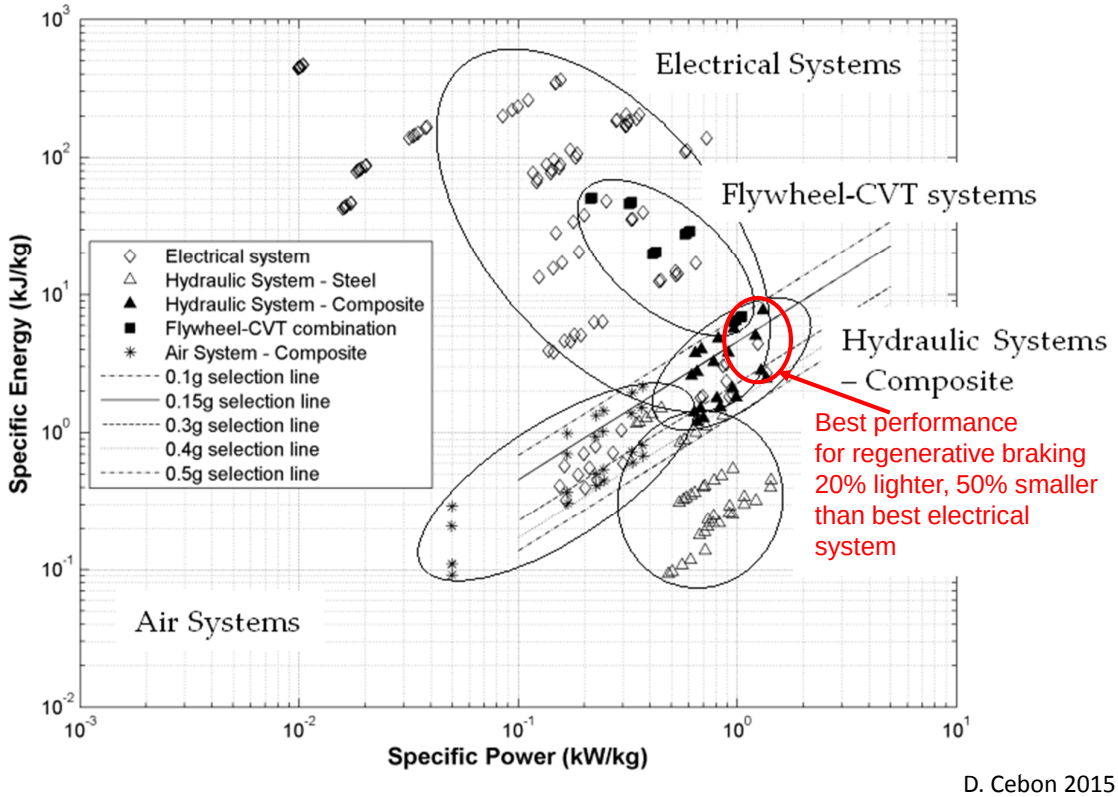
Public Opinion?

Regenerative Braking



Comparison of Regenerative Braking Technologies



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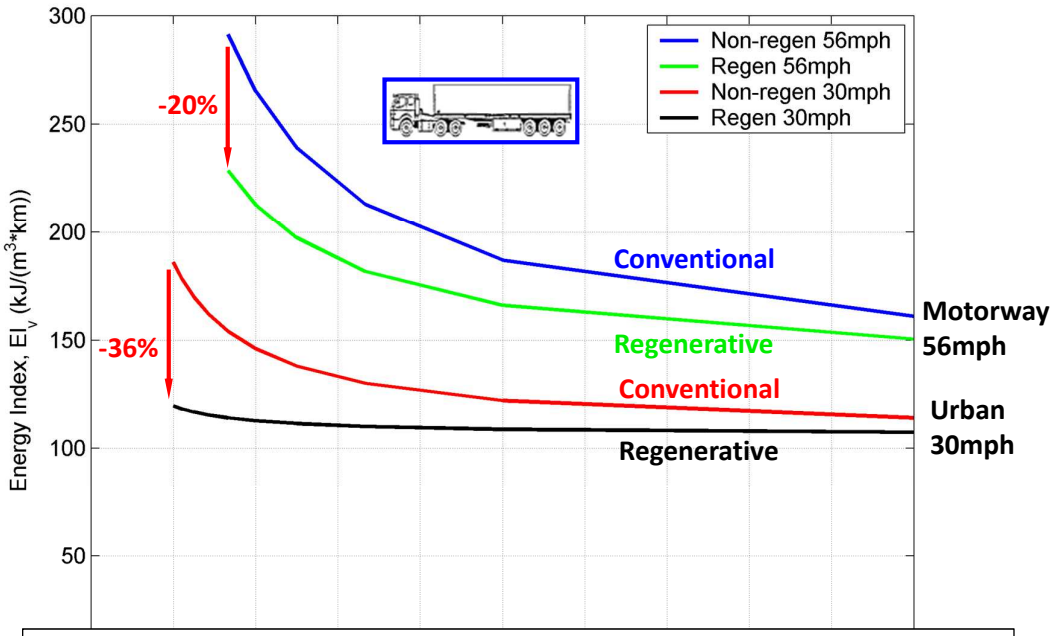
Regenerative Braking (2 tonnes, 3.80MJ, 80%)



- **Insufficient storage for stop from 56mph**
- **Biggest energy saving is for stop-start urban 36%**

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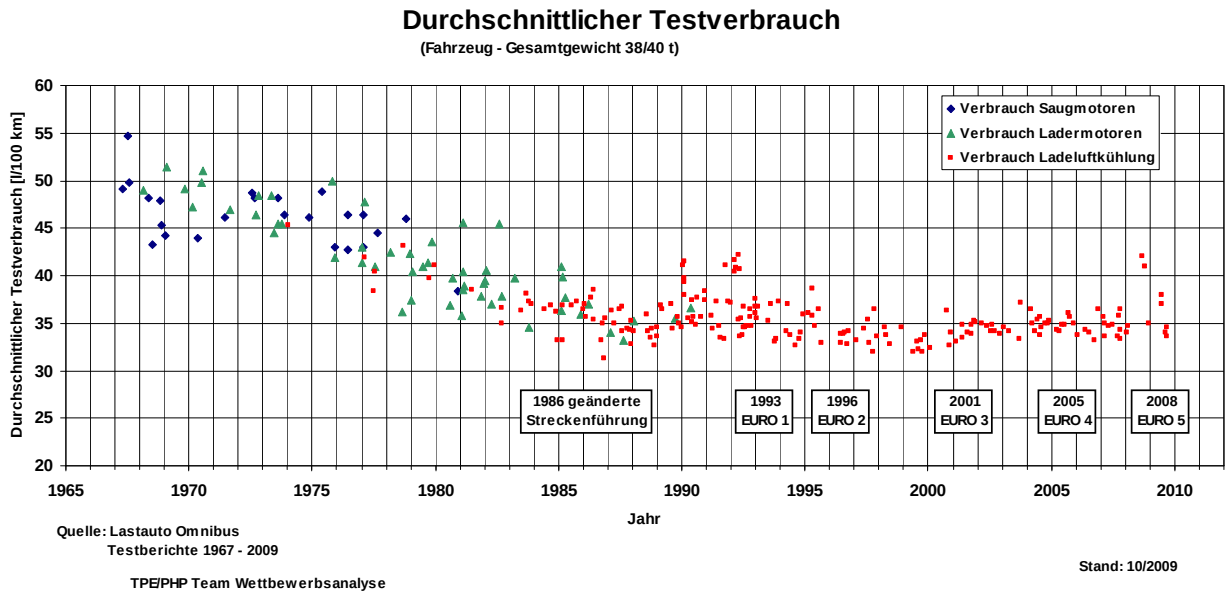
“Lastauto-Omnibus” Data Courtesy Daimler



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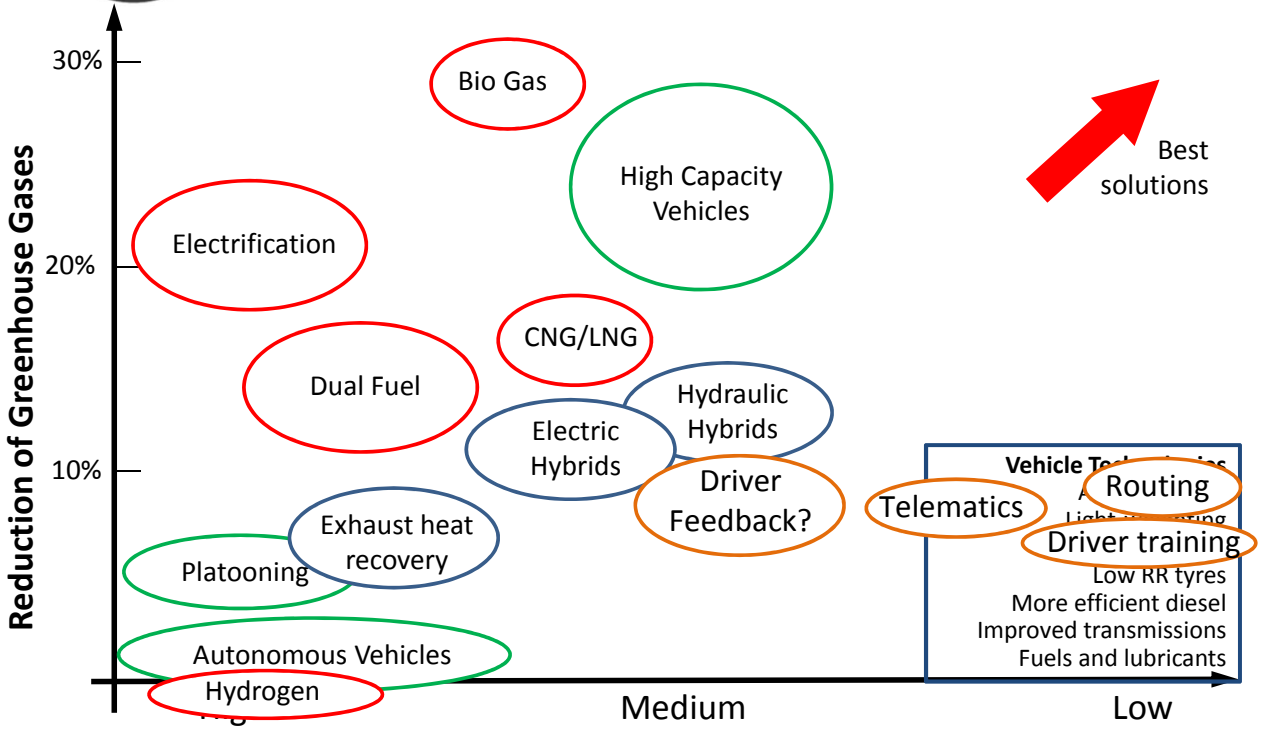
Technologies for reducing fuel consumption and CO2



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.

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Introduction to Centre for Sustainable Road Freight

Heriot Watt University

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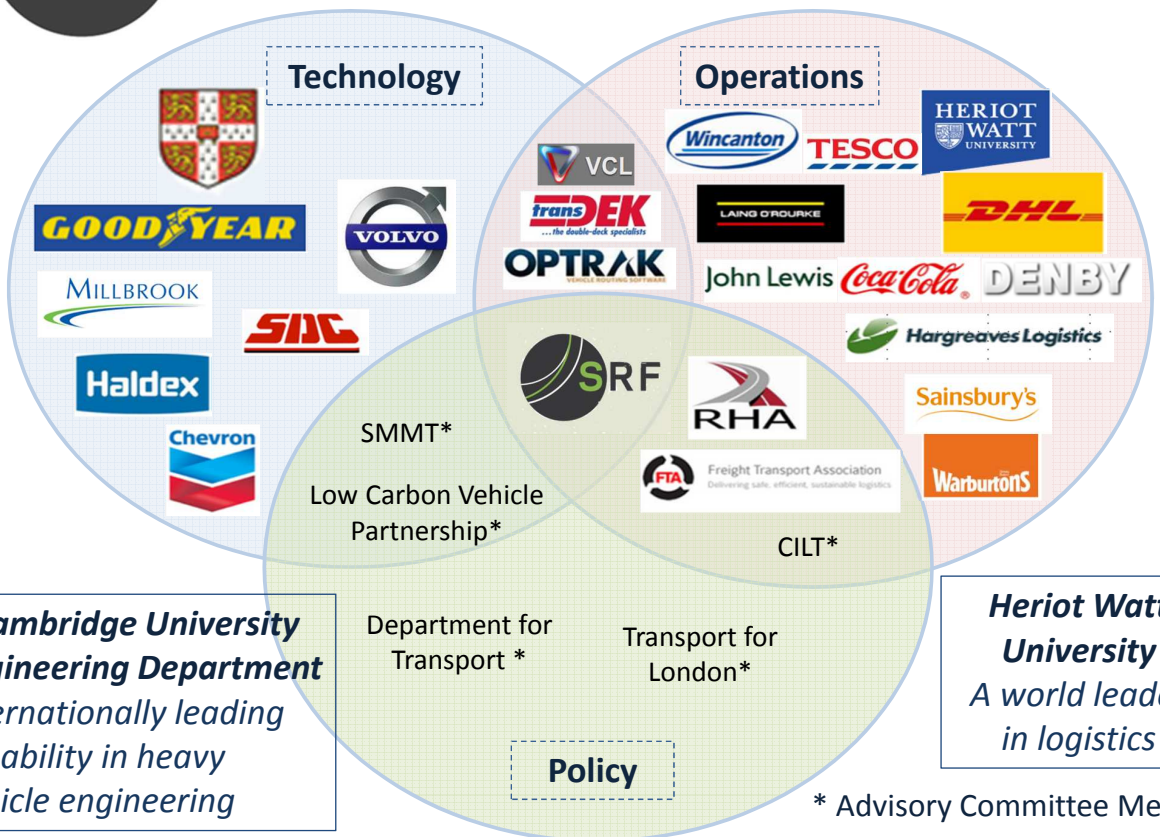
11 July 2013

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

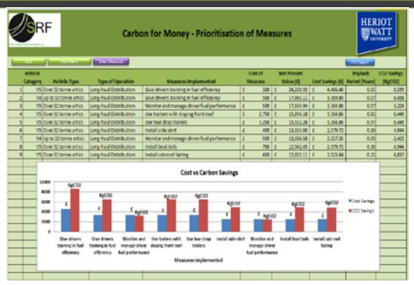
* Advisory Committee Member

Summary of Research Programme

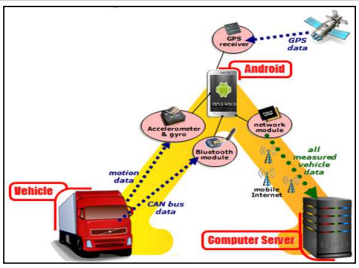
	Technology	Operations	Policy
Core Activities			
Future Mapping	★	★	★
Maximising Impact	★	★	★
Research Portfolio Management	★	★	★
Data Management, Scenario Analysis & Decision Support			
Driver Skills & Training		★	★
Traffic Congestion	★	★	
Carbon for Money Tool		★	
Integrated Logistics Dataset		★	★
Optimising 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…

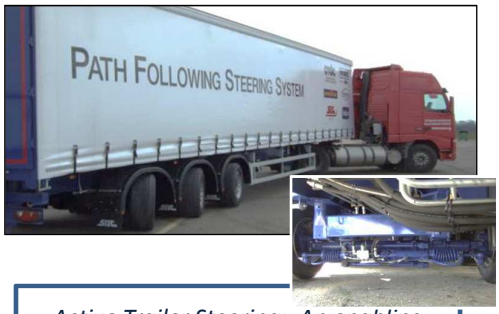
Dynamometer testing of Diesel-CNG dual fuel vehicle performance and emissions



'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…

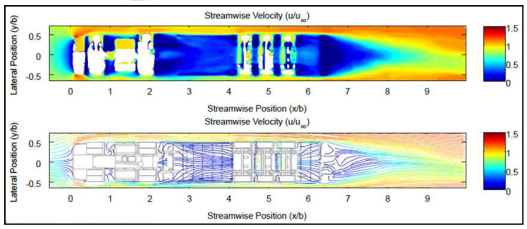


Active Trailer Steering: An enabling technology for higher capacity vehicles. IP licensed to Consortium partner

Task analysis for commercial driving: identification of modern and future training needs from a new perspective

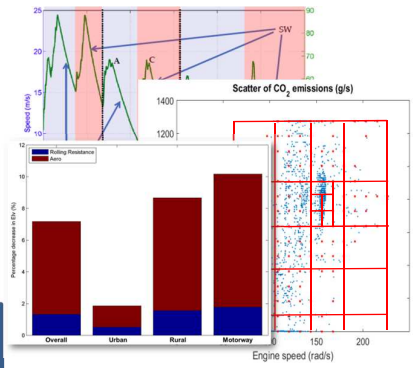
Hydraulic regenerative braking system for urban delivery vehicles

More Research Highlights..

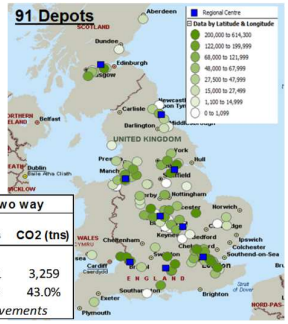


Measurement of vehicle underbody flows and effects of interventions

Aerodynamic improvements on in-service test trailer

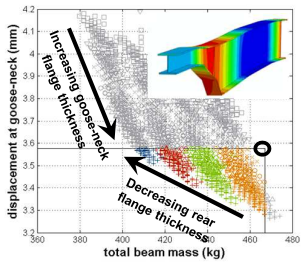


Methods for characterising vehicles and measuring benefits of interventions



Backhaul savings over two way			
Distance			
Cost	(km)	Hours	CO2 (tns)
£3,678,330	3,417,935	60,061	3,259
40.0%	42.7%	38.2%	43.0%
4.8%	*saving over all movements*		

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 CO_2) 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…**

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