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Advances in Trucking Research

Selection of Low Carbon Technologies for Heavy Goods Vehicles

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Introduction

- Background
- How can we decarbonise road freight?
- How the model works ?
- Results
- Summary
- Questions & Answers

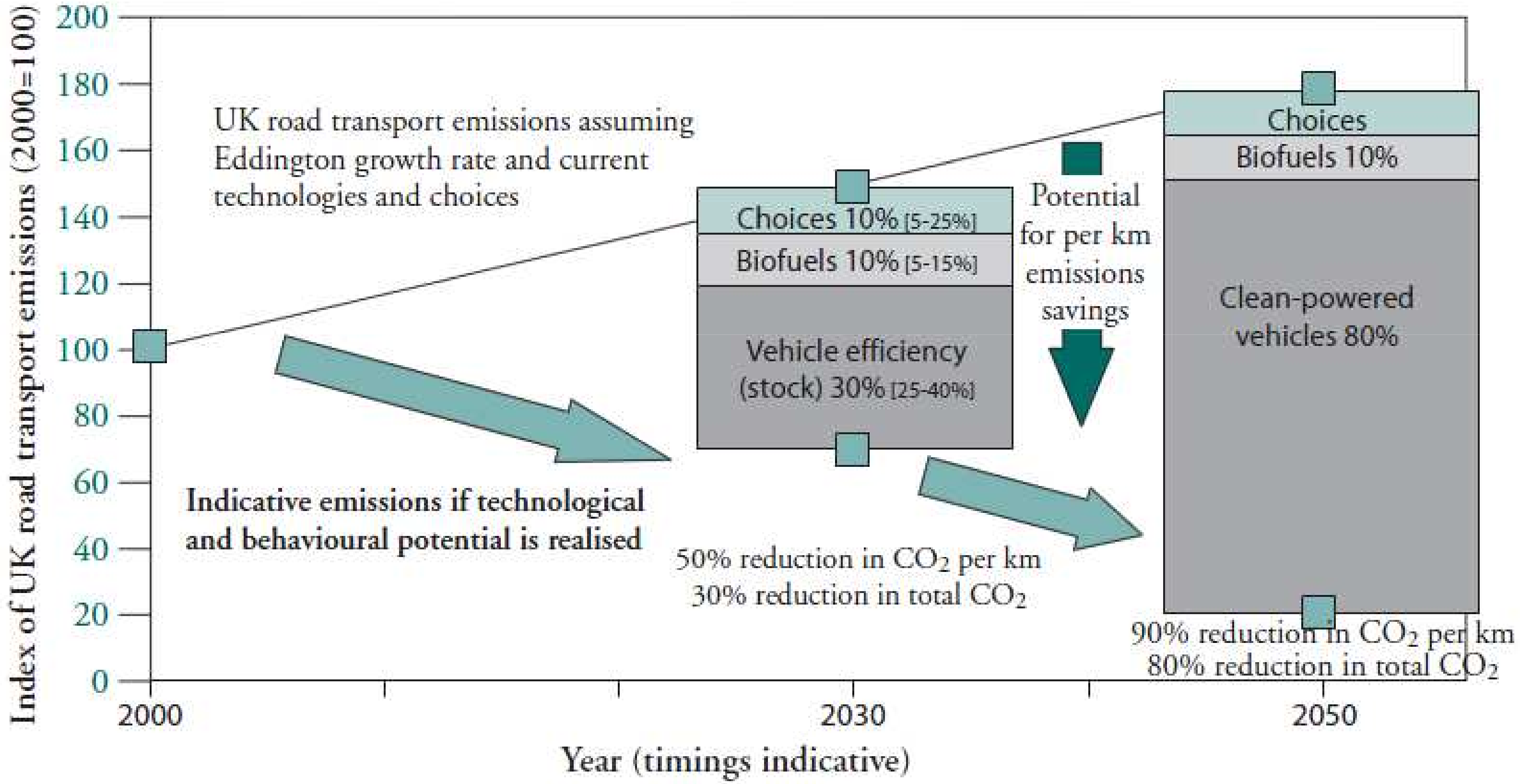
Research Background

Main Objective

Reduce carbon emissions of delivery fleets of urban, regional and long-haul heavy goods vehicles in the most cost efficient way under different scenarios by developing a technology selection model

How to Decarbonise Road Freight?

What Can Be Done?



A pathways towards decarbonising road transport. Source: King (2007)

How Does it Work?

Some of the Inputs

- **Financial parameters**
  - Costs of vehicles and each technology
  - Forecast of fuels and carbon prices, rate of return, rates
- **Operating parameters**
  - Driving Cycle from Telematics
  - Forecast of future activity (i.e. mileage, tonnage, etc.)
- **Technical parameters**
  - Simulation of Fuel Consumption Reduction of each technology according to operating parameters
  - Technology maturity, safety, limitations
- **Constraints**
  - Fuel availability, range of vehicles
  - Compatibility among technologies

Financial Parameters

Technologies		Additional Costs		
	Duty Cycle	Urban (£)	Regional (£)	Long haul (£)
Vehicle Technologies	1 Aerodynamic Trailers	3,242	3,242	3,242
	2 Aerodynamic Irregular body shape	815	815	815
	3 Aerodynamic Fairings	1,093	1,093	1,093
	4 Spray Reduction Mud Flaps	129	129	172
	5 Low rolling resistance tires	324	324	324
	6 New generation wide-base single tires	764	764	1,204
	7 Automatic tire pressure adjustment	10,921	10,921	10,921
	8 Lightweighting Materials	347	347	1,482
	9 Predictive Cruise Control	1,297	1,297	1,297
	10 Controllable air compressor	130	130	176
Powertrain Technologies	11 Heat Recovery (in general)	10,717	10,717	10,717
	12 Electrical Drive Turbocompound	6,484	6,484	6,484
	13 Automated Manual Transmission	3,242	3,242	4,369
	14 Flywheels Hybrid	3,242	3,242	5,465
	15 Stop-Start: Electric	593	593	871
	16 Pneumatic Booster - Air Hybrid	741	741	741
	17 Full Hybrid: Series / Parallel Electric	22,232	22,232	22,232
	18 Series / Parallel hydraulic	12,227	12,227	12,227
	Refrigeration (-20°C Frozen)	6.2m/33.42 m3	0.4m/61.15 m3	13.4/78.79 m3
Refriger.	19 3 phase alternator Unit	4,000	5,000	5,000
	20 Hybrid Refrigeration Unit	2,000	3,000	3,000
	21 Vacuum Isolated Panels	1,290	2,163	2,787

Technical Parameters: Simulation of FCRs

… Import the route from Google Maps

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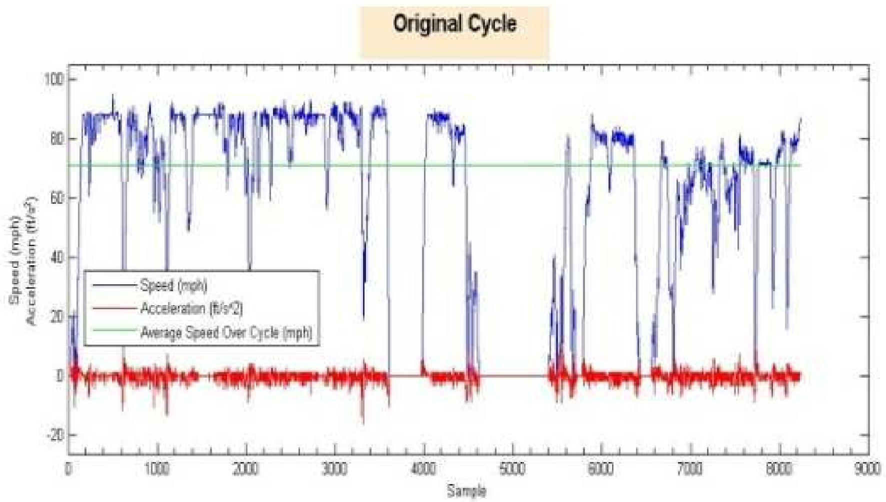
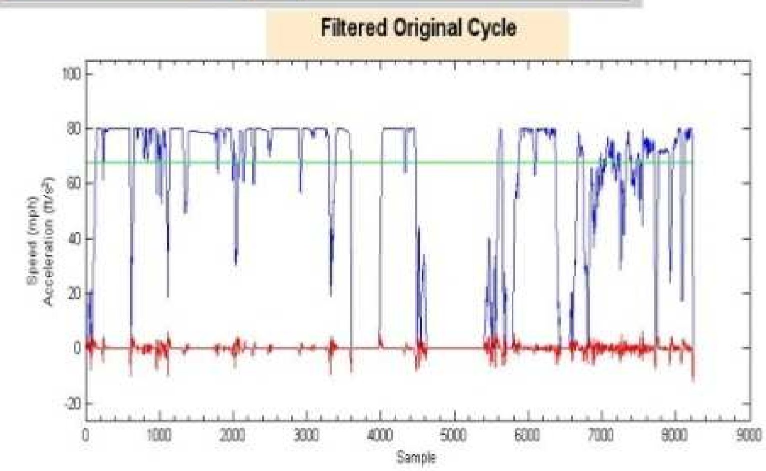
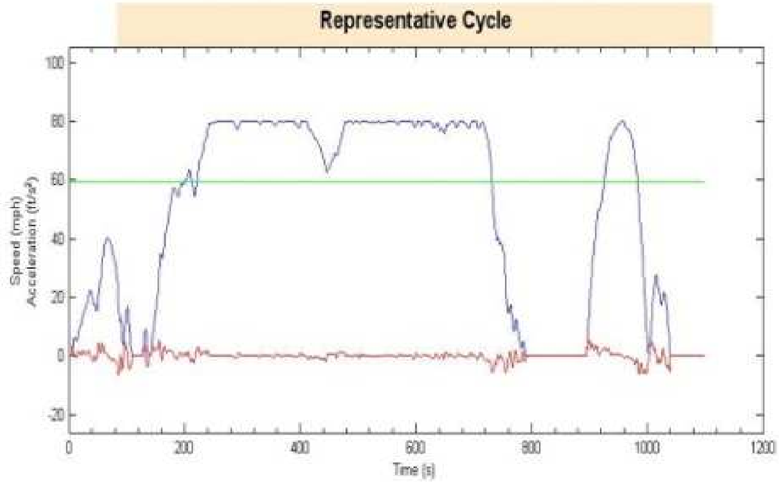
Operating Parameters: Driving Cycle

Telematics
+
Statistical Analysis







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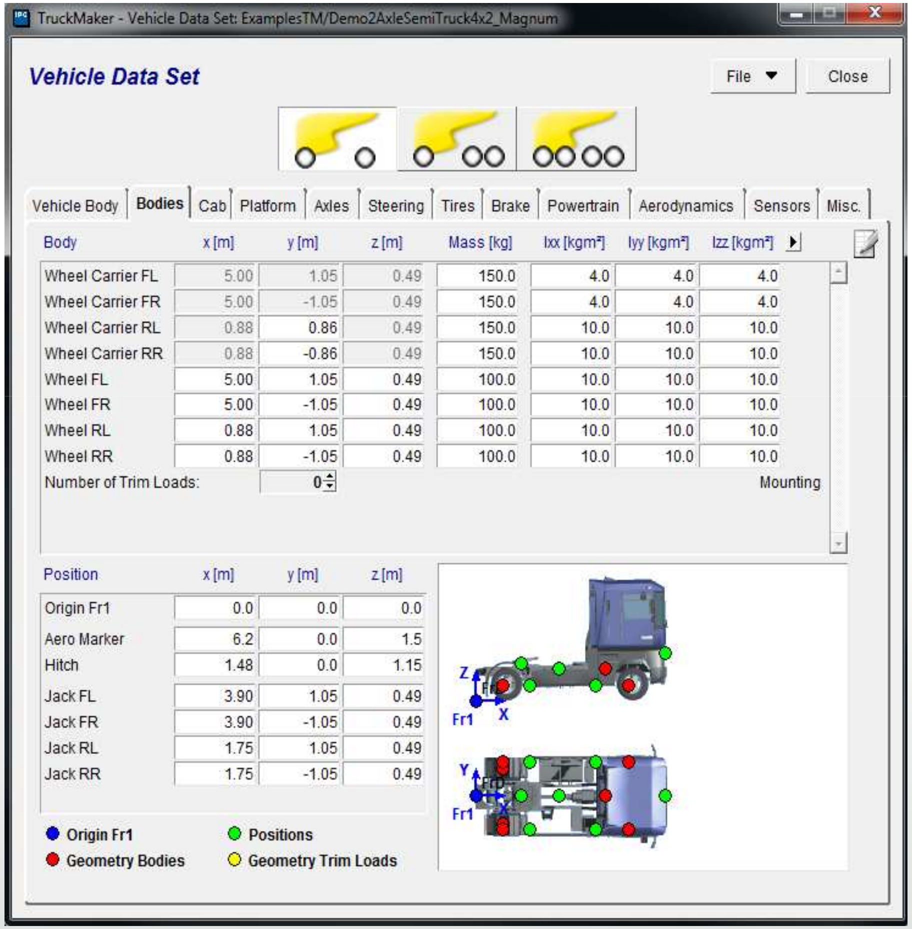
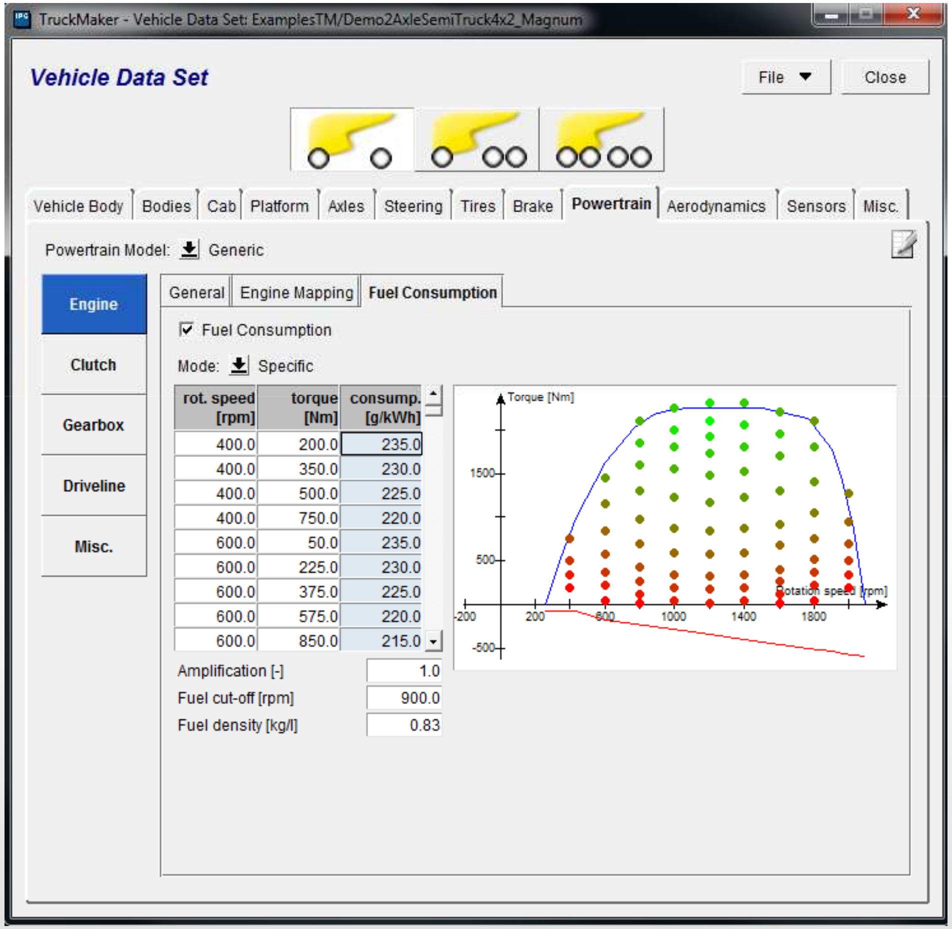
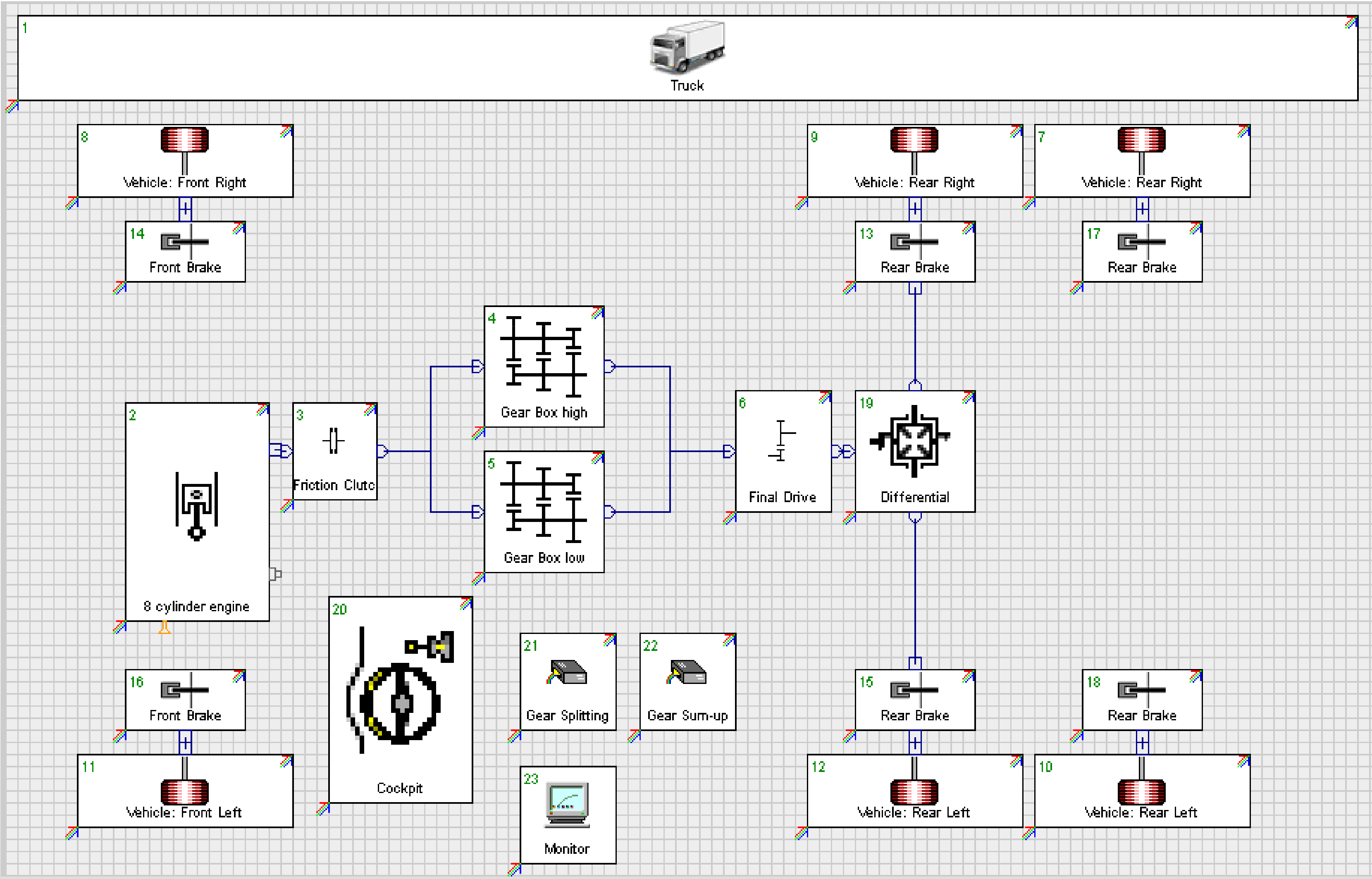
Technical Parameters: Simulating HGVs



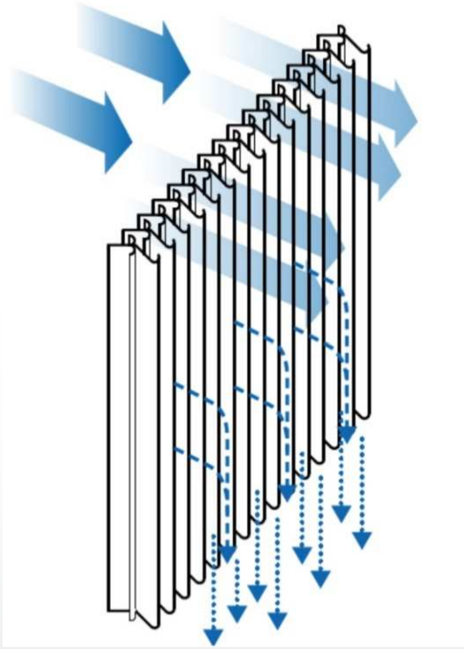


Technical Parameters: Powertrains



Examples of Technologies

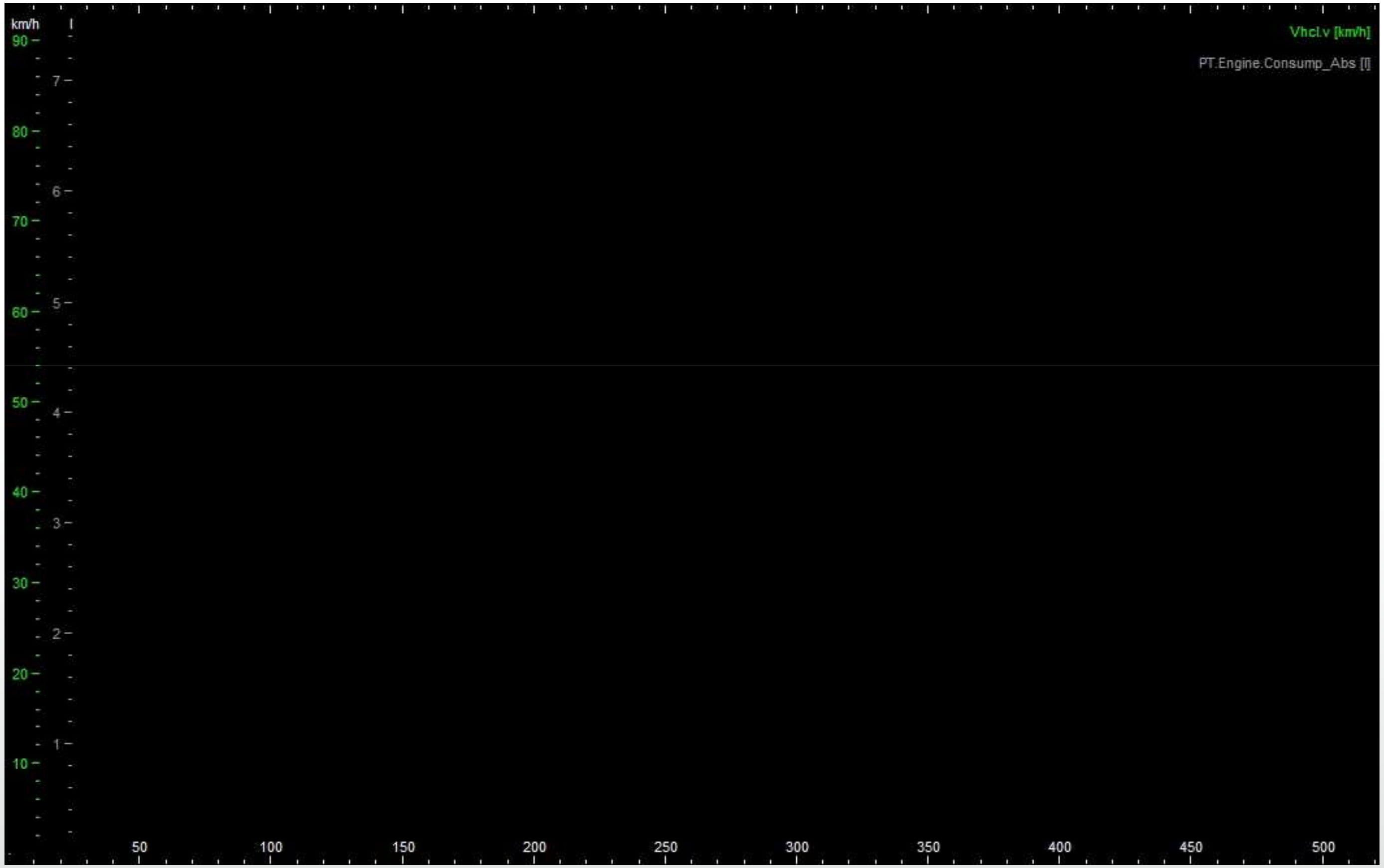
Flywheels



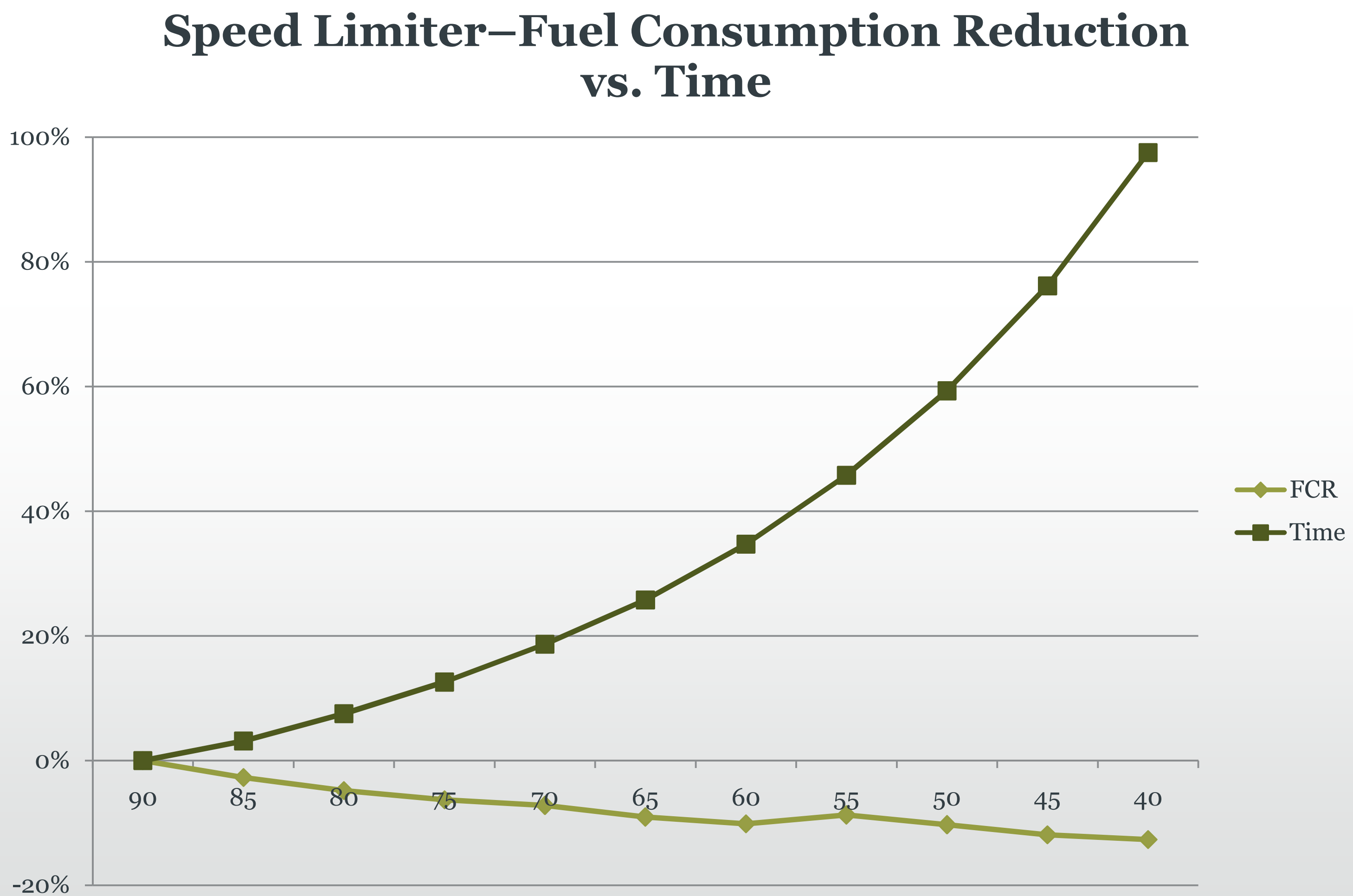
Spray Reduction

Simulating Technologies

Simulation Results



Experiments: Speed Limiter



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Technical Parameters

Group	Technologies	Fuel Consumption Reduction Urban (%)	Regional (%)	Long haul (%)
	Duty Cycle			
Vehicle Technologies	1 Aerodynamic Trailers	1.0	11.0	11.0
	2 Aerodynamic Irregular body shape	1.0	6.5	5.0
	3 Aerodynamic Fairings	0.0	1.0	0.4
	4 Spray Reduction Mud Flaps	0.5	1.0	2.0
	5 Low rolling resistance tires	1.0	3.0	5.0
	6 New generation wide-base single tires	4.0	6.0	5.0
	7 Automatic tire pressure adjustment	1.0	2.0	3.0
	8 Lightweighting Materials	2.2	2.2	2.2
	9 Predictive Cruise Control	0.0	5.0	5.0
	10 Controllable air compressor	0.0	1.0	1.5
Powertrain Technologies	11 Heat Recovery (in general)	1.5	2.5	5.0
	12 Electrical Drive Turbocompound	1.0	2.5	3.0
	13 Automated Manual Transmission	5.0	1.5	5.0
	14 Flywheels Hybrid	15.0	7.5	5.0
	15 Stop-Start: Electric	6.0	3.0	1.0
	16 Pneumatic Booster - Air Hybrid	1.5	1.5	3.5
	17 Full Hybrid: Series / Parallel Electric	20.0	10.0	7.0
	18 Series / Parallel hydraulic	10.0	0.0	0.0
	Refrigeration (-20°C Frozen)	6.2m/33.42 m3	0.4m/61.15 m3	13.4/78.79 m3
Refriger.	19 3 phase alternator Unit	100.0	100.0	100.0
	20 Hybrid Refrigeration Unit	11.0	11.0	11.0
	21 Vacuum Isolated Panels	1.0	5.0	5.0

Outputs

- Lowest net present cost of a vehicle during its 5 years lifetime
- Carbon Emissions for the vehicle specified

Yes, but how is it done?

Optimisation through scatter and tabu search

Evolutionary algorithm ideal for non-linear, non-smooth complex problems

$$\text{FCR}(\%) = 100 \times \left[1 - \prod_{i=0}^{n}(1 - \%FCR_i)\right]$$

As 21 technologies are evaluated a total of 2,097,152 combinations have to be tested with multiple ‘if’ and ‘or’ conditions making this problem complex to solve in a reasonable time by any other method.

… 100 different technology combinations would require the evaluation of a total of 2^{100} (1.26 x 10^{30}) outcomes

Results

Operating Parameters									
			Type of Fuel	B65		DERV		DERV	
			Scenario	1	2	3	4	5	6
			Duty Cycle Type	Urban	Regional	Urban	Regional	Urban	Urban
Results									
Vehicle Technologies	Reduced Aerodynamic Resistance	1	Aerodynamic Trailers	0	1	0	1	0	0
		2	Aerodynamic Irregular body shape	0	0	1	0	1	1
		3	Aerodynamic Fairings	0	0	0	0	0	0
		4	Spray Reduction Mud Flaps	1	1	1	1	1	1
	Reduced Rolling Resistance	5	Low rolling resistance tires	0	0	0	0	0	0
		6	New generation wide-base single tires	1	1	1	1	1	1
		7	Automatic tire pressure adjustment	0	0	0	0	0	0
	Vehicle Mass	8	Lightweighting Materials	1	1	1	1	1	1
	Intelligent VT	9	Predictive Cruise Control	0	1	0	1	0	0
	Auxiliary Systems	10	Controllable air compressor	0	1	0	1	0	0
PowerTrain Technologies	Exhaust Heat Recovery	11	Heat Recovery (in general)	0	0	0	0	0	0
		12	Electrical Drive Turbocompound	0	0	0	0	0	0
	Transmissions	13	Automated Manual Transmission	1	0	1	0	1	1
	Mild Hybrid	14	Flywheels Hybrid	1	1	1	1	1	0
		15	Stop-Start: Electric Hybrid	0	0	0	0	0	0
		16	Pneumatic Booster - Air Hybrid	0	0	0	0	0	0
	Alternative PT	17	Full Hybrid: Series / Parallel Electric	0	0	0	0	0	0
		18	Series / Parallel hydraulic	0	0	0	0	0	0
	Total FCR (Vehicle & Powertrain)			-24.56%	-29.53%	-25.32%	-29.53%	-25.32%	-12.14%
TRU	Refrigeration Technologies	19	3 phase alternator Unit	0	0	0	0	0	1
		20	Hybrid Refrigeration Unit	0	0	0	0	0	0
		21	Vacuum Isolated Panels	0	0	0	0	0	0
	Total FCR (TRU)			0%	0%	0%	0%	0%	100%
	Combined FCR (Vehicle, Powertrain & Refrigeration)			-21.34%	-26.11%	-21.75%	-25.85%	-18.66%	-30.74%
	Carbon Emissions Baseline (t CO2 eq)			199.9	218.8	399.7	449.0	464.5	464.6
	Carbon Emissions Solution (t CO2 eq)			169.2	176.3	317.4	338.5	382.3	324.9
	Carbon Emissions			-15.38%	-19.41%	-20.58%	-24.61%	-17.71%	-30.07%
Net Present Costs									
	Baseline			£234,469	£251,099	£248,797	£267,602	£262,116	£262,123
	Optimised Solution			£217,006	£225,373	£227,748	£237,003	£241,067	£241,070
	Costs			-7.45%	-10.25%	-8.46%	-11.43%	-8.03%	-8.03%

Summary

Key Points

- Cost savings between 7.5% and 11.5% can be achieved with GHG savings between 15% and 25% depending on duty cycle and operating parameters
- The model can include more technologies which may lead to higher savings and it can be adapted to different fleets and operating conditions
- Simulation can save a lot of money and time avoiding real world trials and it is the only reasonable way of testing millions of technology combinations

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Any Questions ???