

Decarbonizing Road Freight Transport

Professor Alan McKinnon

Kühne Logistics University

Climate plans and climate budgets: what does this mean for road freight transport?

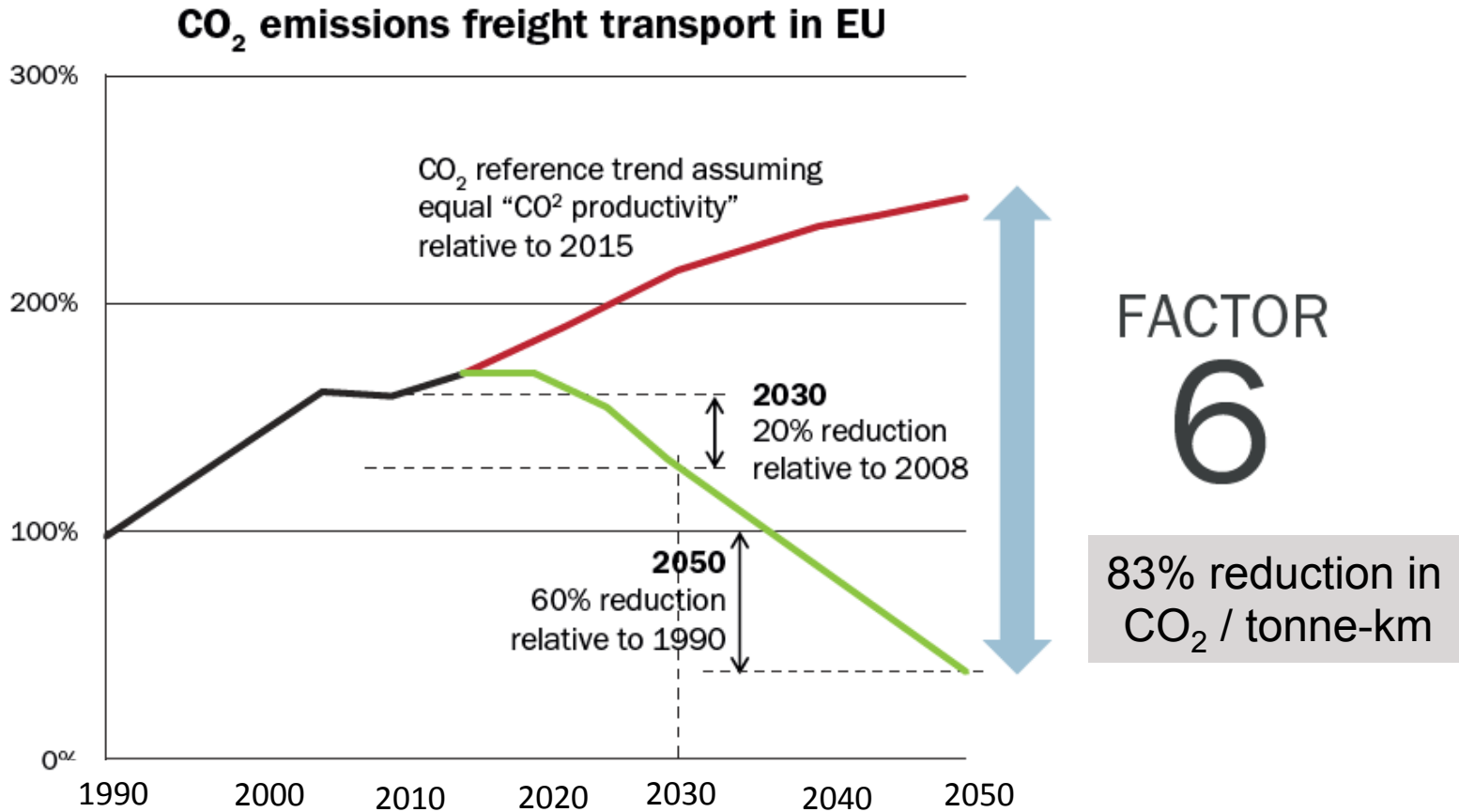
Energy Fund / Concito Workshop

Copenhagen

14 May 2019

Meeting EU 2011 Transport White Paper CO₂ Target for 2050

Reduction in carbon intensity need to achieve 60% cut in total freight-related emissions



Source: Smokers et al. (2017). *Decarbonising Commercial Road Transport*. Delft: TNO.

Leveraging freight decarbonisation parameters to achieve a Factor 6 reduction by 2050

30% modal shift road to rail
*Rail improves energy efficiency by 50%
and reduces carbon intensity of energy by 50%*

+

20% improvement in routeing efficiency

+

30% increase in loading of laden vehicles

+

30% reduction in empty running

+

50% increase in energy efficiency

+

50% reduction in carbon intensity of the energy



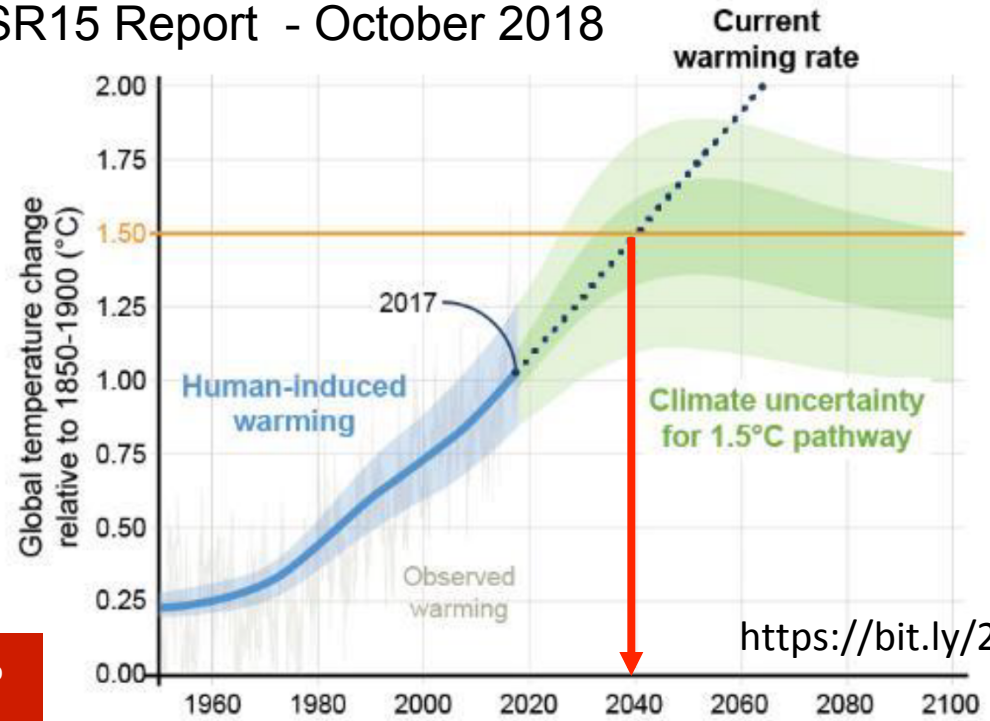
80% reduction in carbon intensity



achievable even in 35 years ?

may not be able meet the absolute CO₂ reduction target without restraining the growth in freight movement

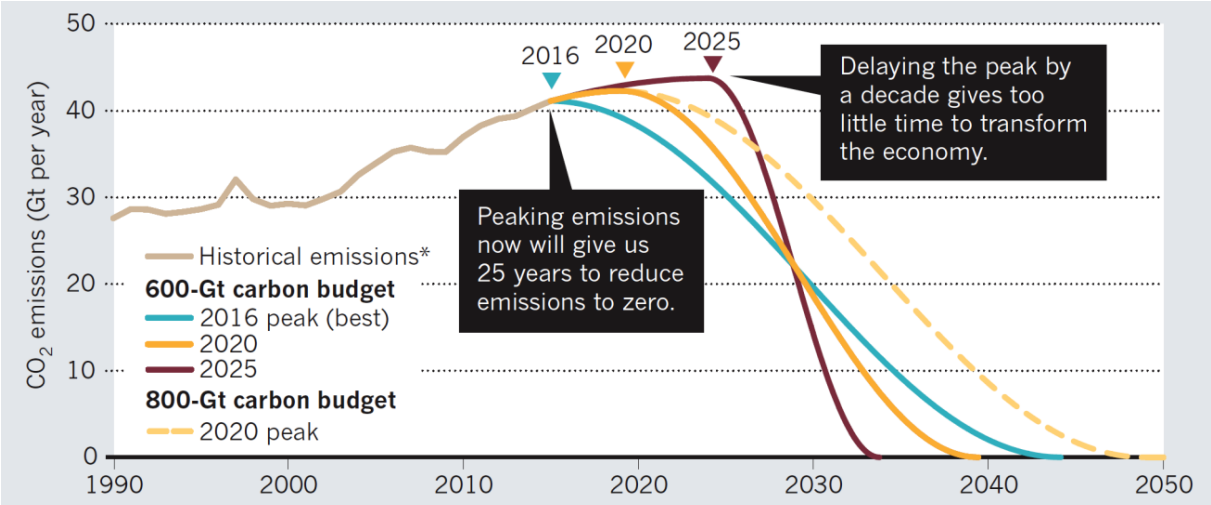
IPCC SR15 Report - October 2018



<https://bit.ly/2AsMPky>

Need to cut CO₂ emissions globally by 50% by 2030 and end them by 2050

Need to stay within tight carbon budgets to limit temperature rise to 1.5-2.0°C

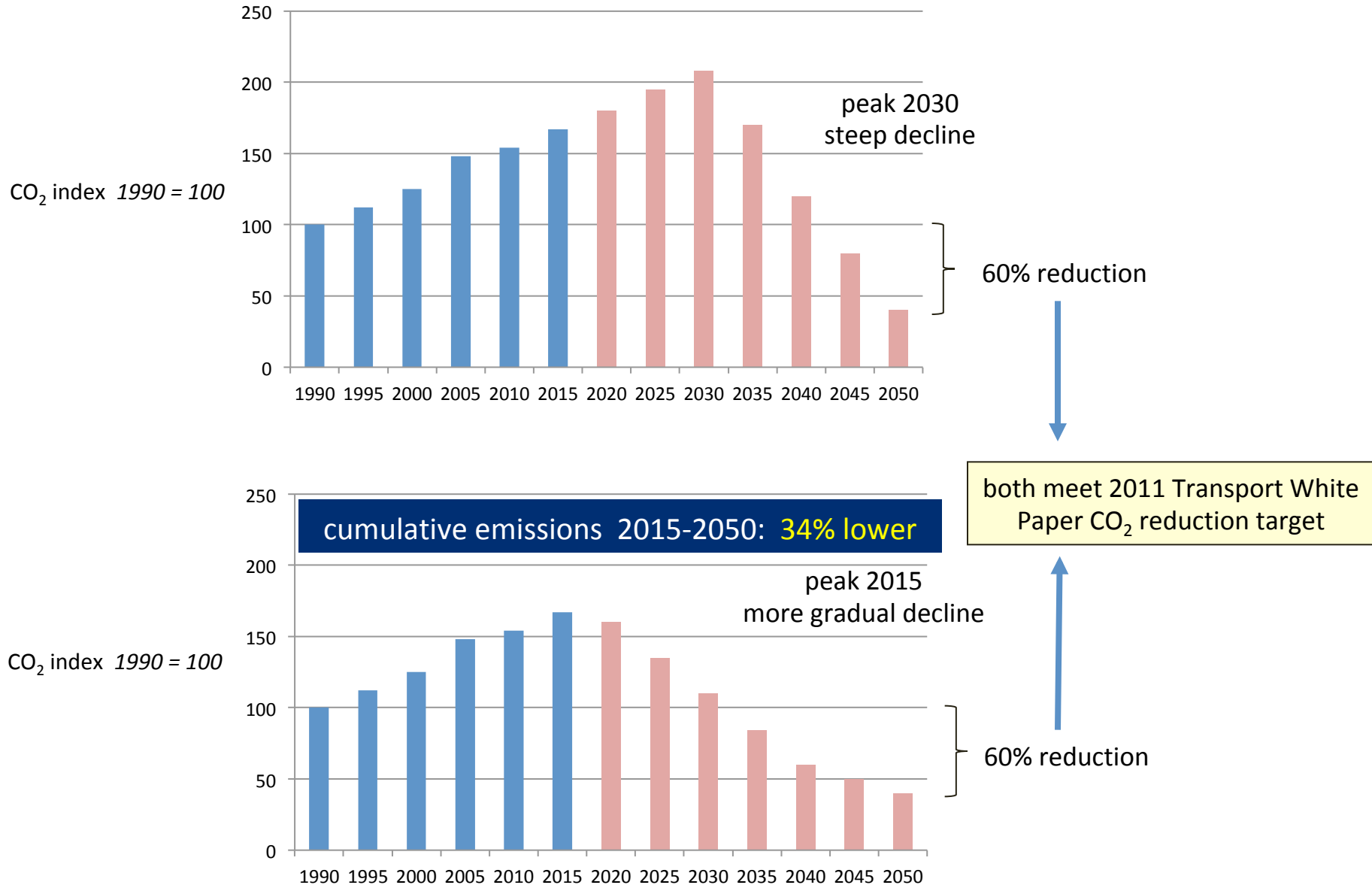


Source: Figueres et al, *Nature* June 2017

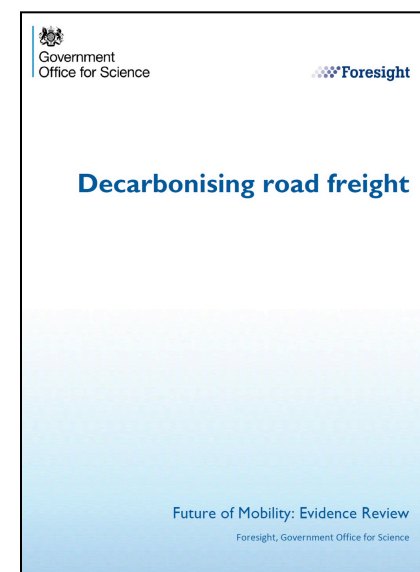
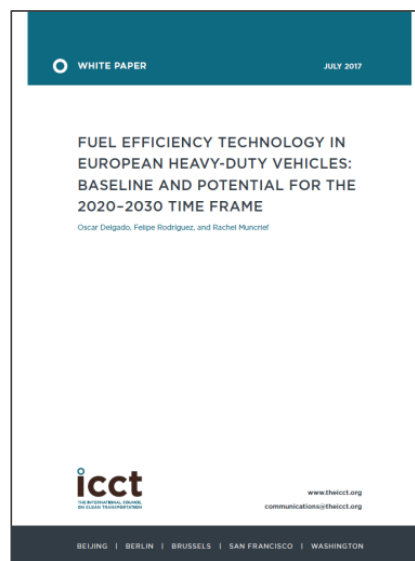
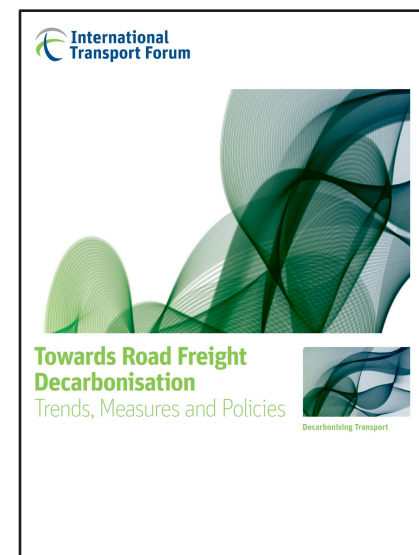
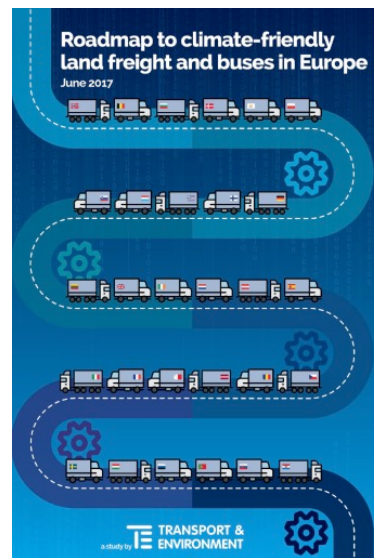
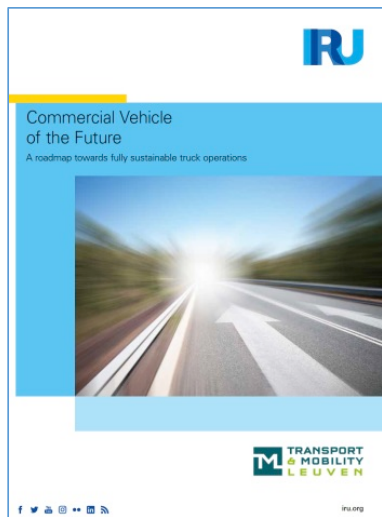
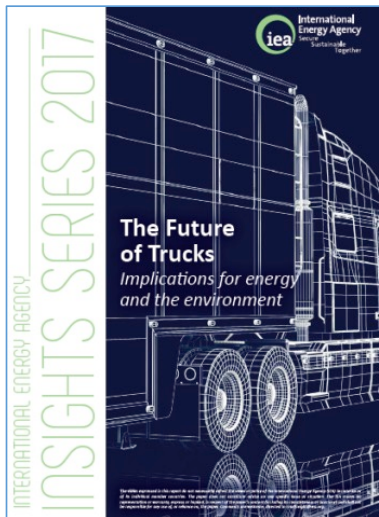
*Data from The Global Carbon Project.

<https://bit.ly/2WGTINT>

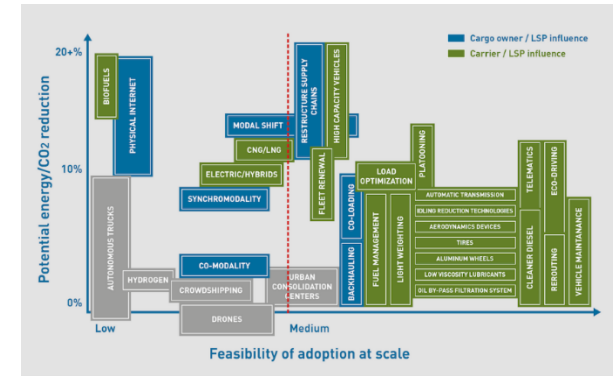
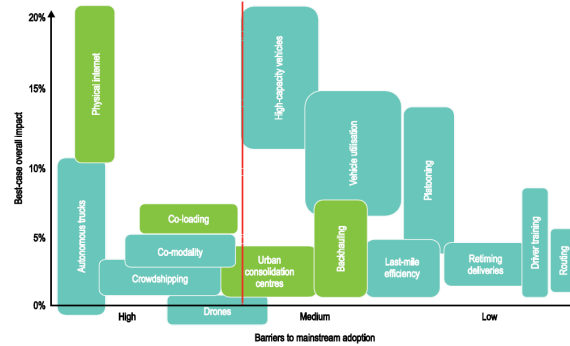
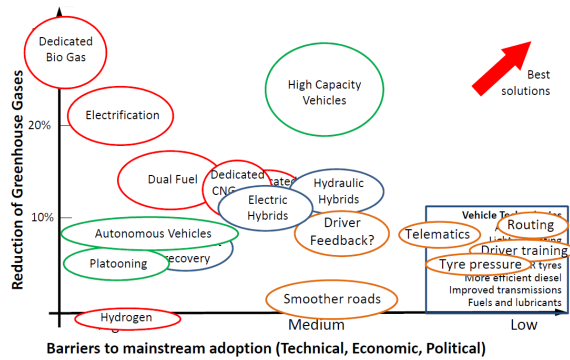
CO₂ emission reduction profiles for European freight transport



Examples of recent reports on the decarbonisation of road freight



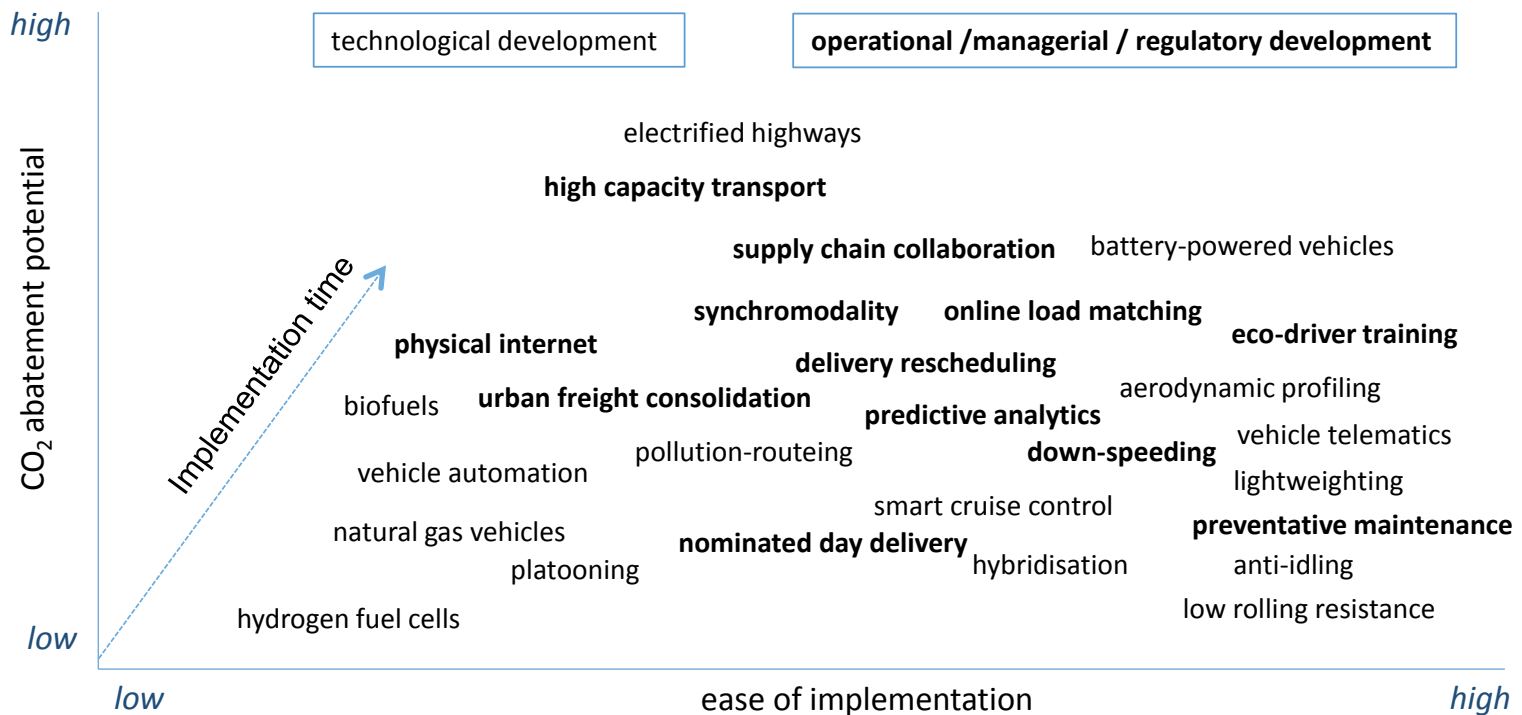
Road freight decarbonisation measures: *abatement – implementation graphs*



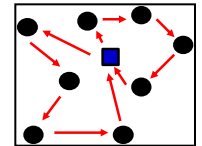
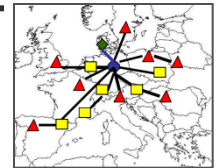
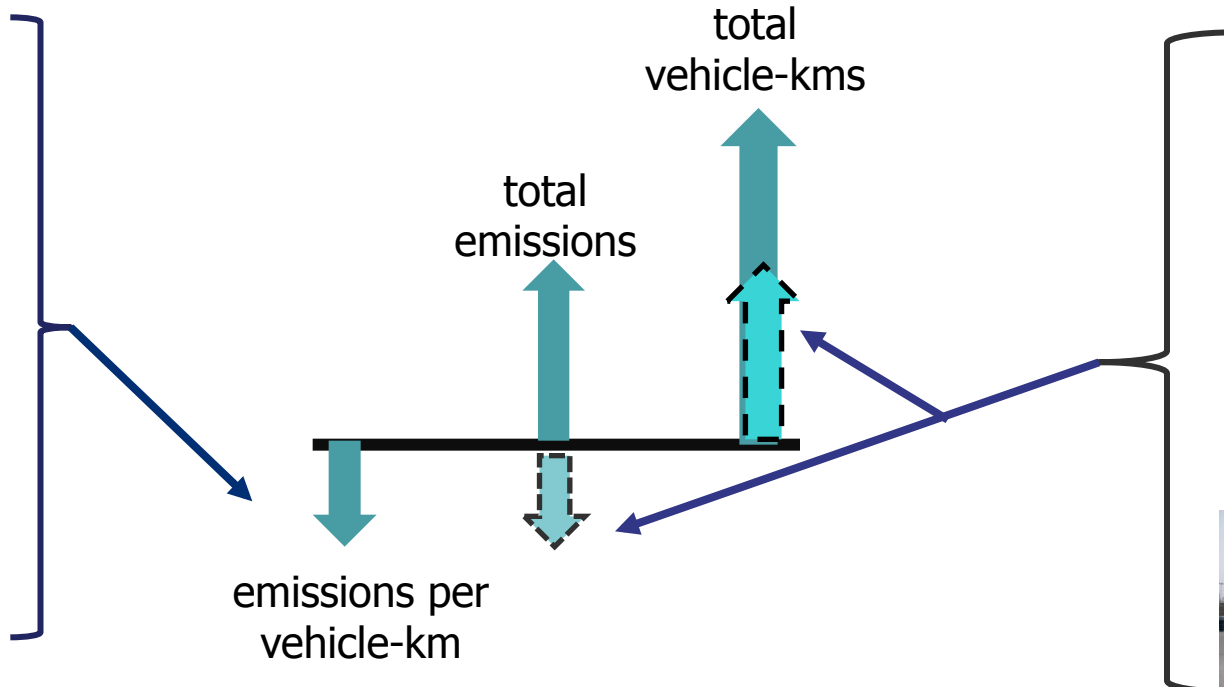
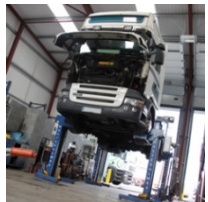
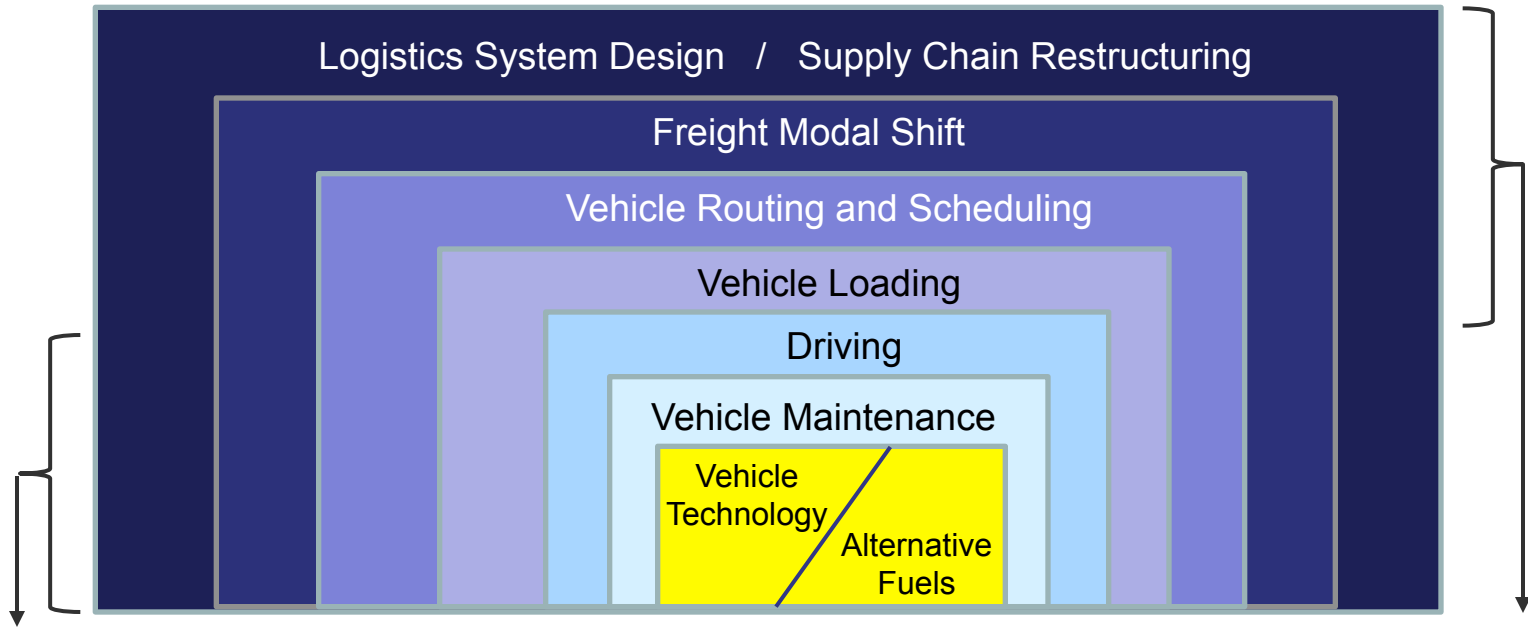
Professor Cebon

International Energy Agency

Smart Freight Centre



Scoping the Decarbonisation of Road Freight Transport



Five Categories of Freight Decarbonisation Measure

reduce level of freight movement

- relocalize / decentralize
- circular and sharing economy
- digitisation
- 3D printing
- route optimisation

shift freight to lower carbon modes

- synchromodality
- intermodal corridor strategies
- infrastructural enhancement
- internalise environmental cost

improve vehicle loading

- logistical collaboration
- relax JIT pressures
- online load matching
- liberalise high capacity transport
- consolidate urban deliveries

logistics
management
behaviour
regulation

increase energy efficiency

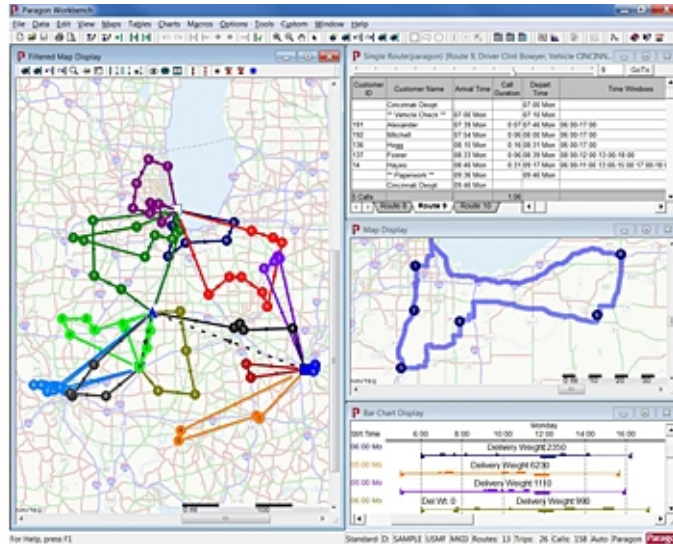
- energy-saving technologies
- fuel economy standards
- eco-driving: training / monitoring
- platooning / automation

switch to low carbon energy

- low carbon electrification
- switch to bio-fuels
- electrifying infrastructure
- refuelling / recharging networks

technology
engineering
energy supply

Optimising Vehicle Routing



Can reduce the distance travelled by freight consignments – *cutting freight transport intensity*
Yields economic and environmental benefits – ‘win – win’ option

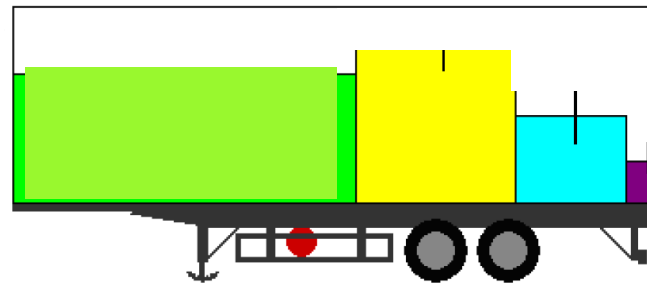
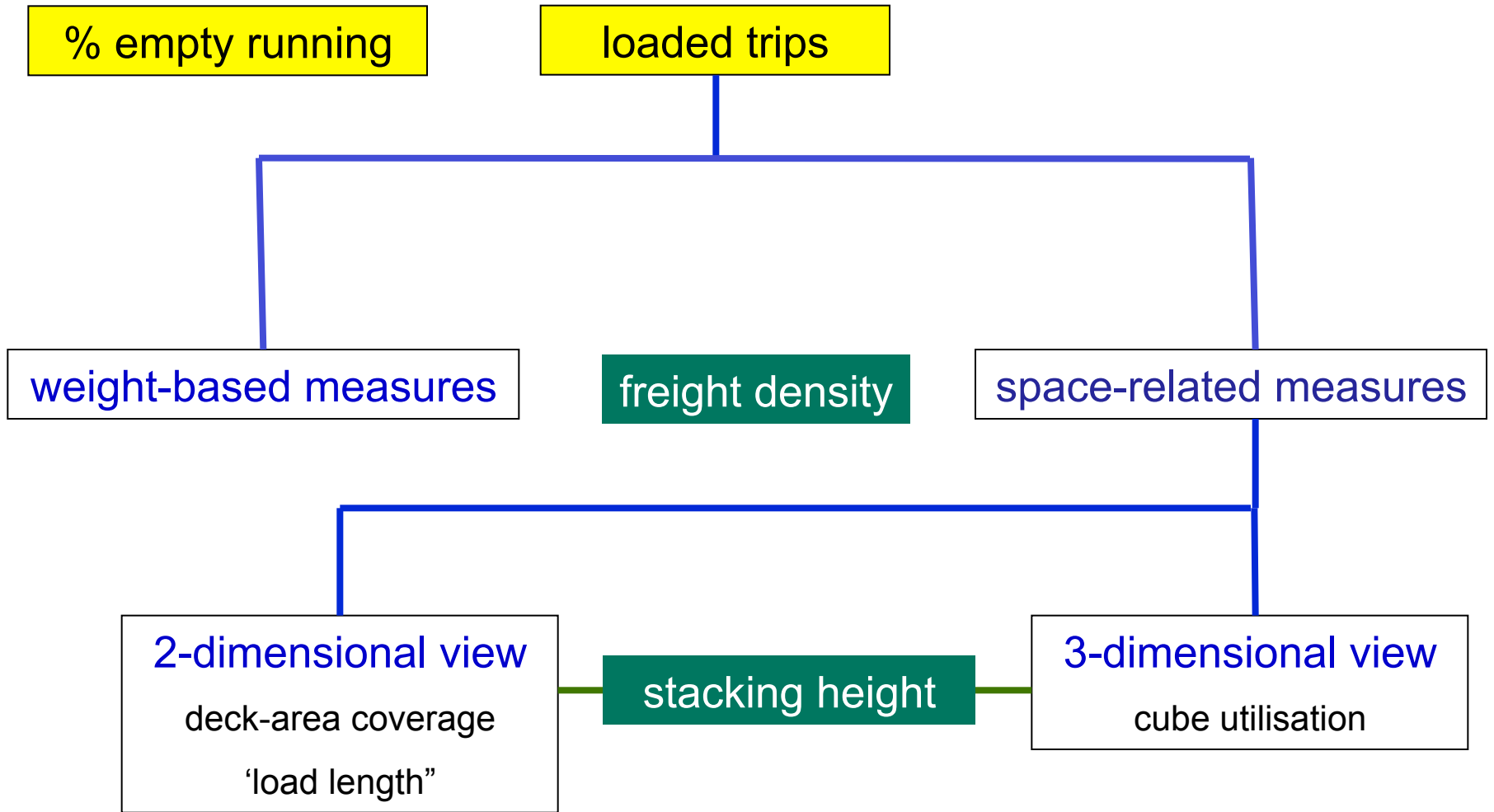
Use of computerised vehicle routing and scheduling (CVRS) software to optimise routes

Widely adopted technology / management tool in developed countries but being upgraded:

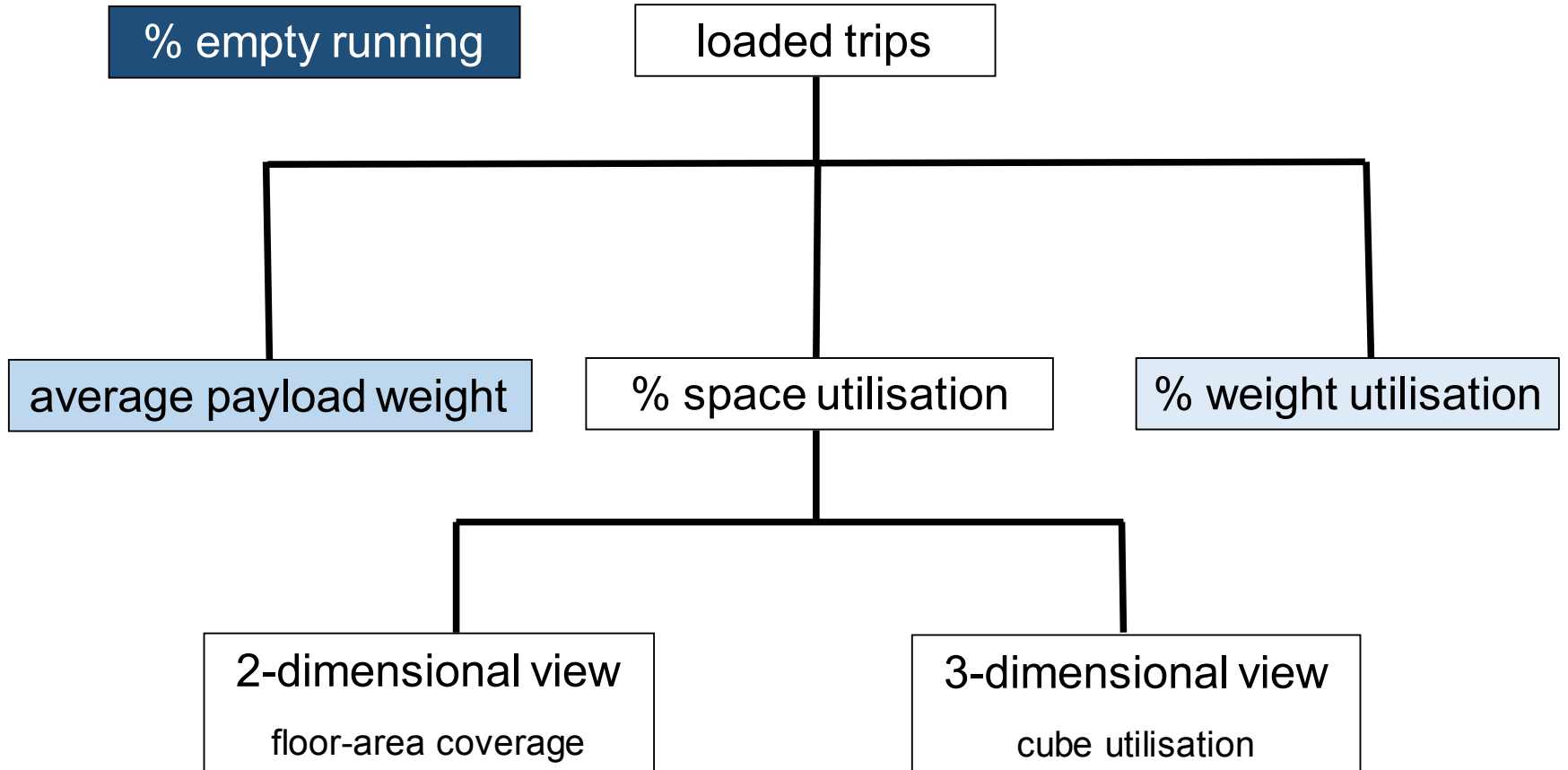
- as vehicles becoming more intelligent and connected – *dynamic re-routing of vehicles*
- use of predictive analytics and big data
- possible recalibration of optimization to minimize emissions - ‘*pollution routing*’

Improve vehicle utilisation

Measurement of Vehicle Utilisation: *key parameters*



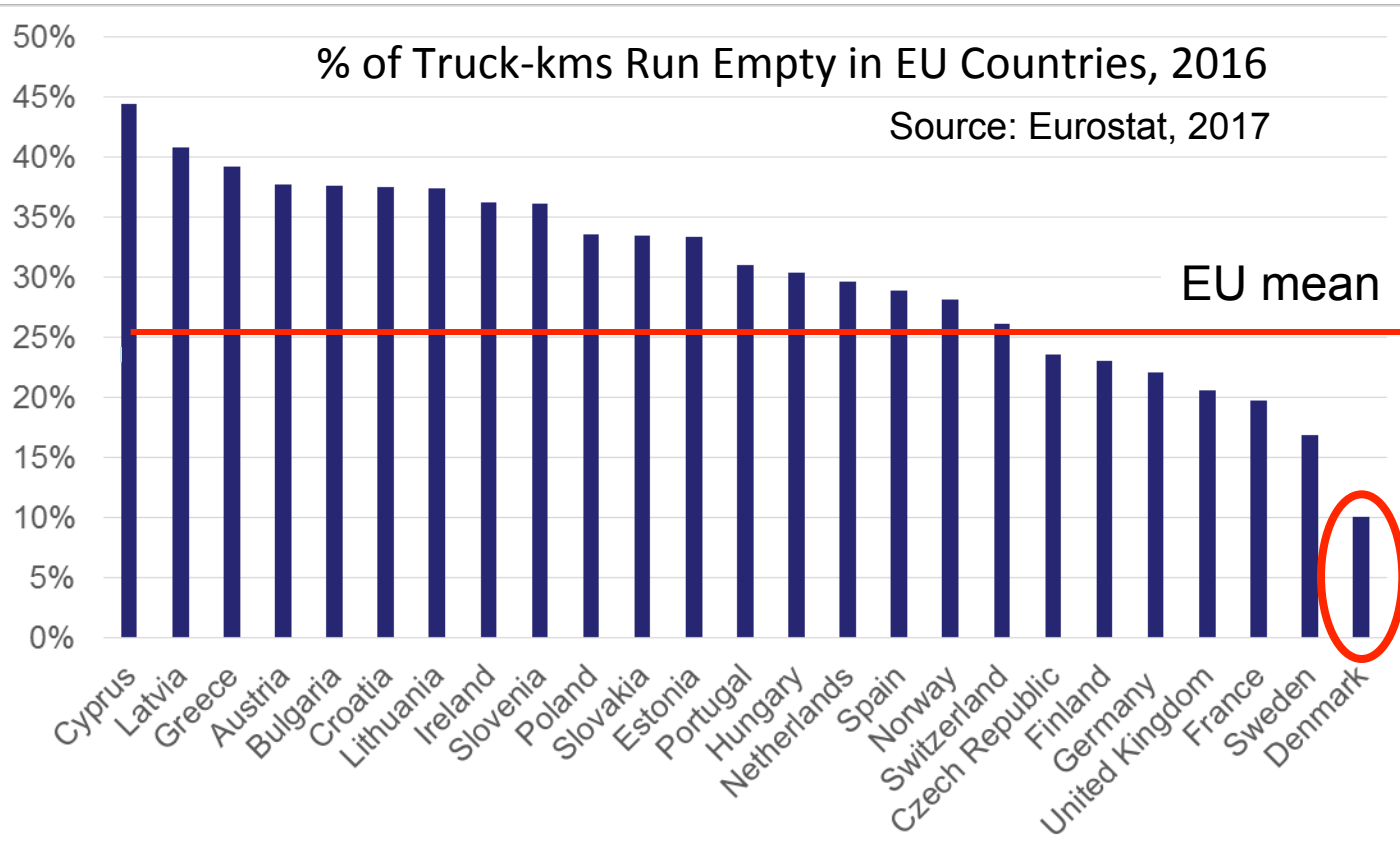
Availability of macro-level truck utilisation data in Europe



Empty Running of Trucks

% of Truck-kms Run Empty in EU Countries, 2016

Source: Eurostat, 2017



Is this figure accurate?
If so, how is it possible?

Constraints on Return Loading

Requirements of the outbound service

Inadequate knowledge of available backloads

Unreliability of the backloading operation

Incompatibility of vehicles and products

Need to recover handling equipment

Poor matching of locations and schedules

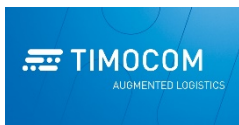
Journey length too short



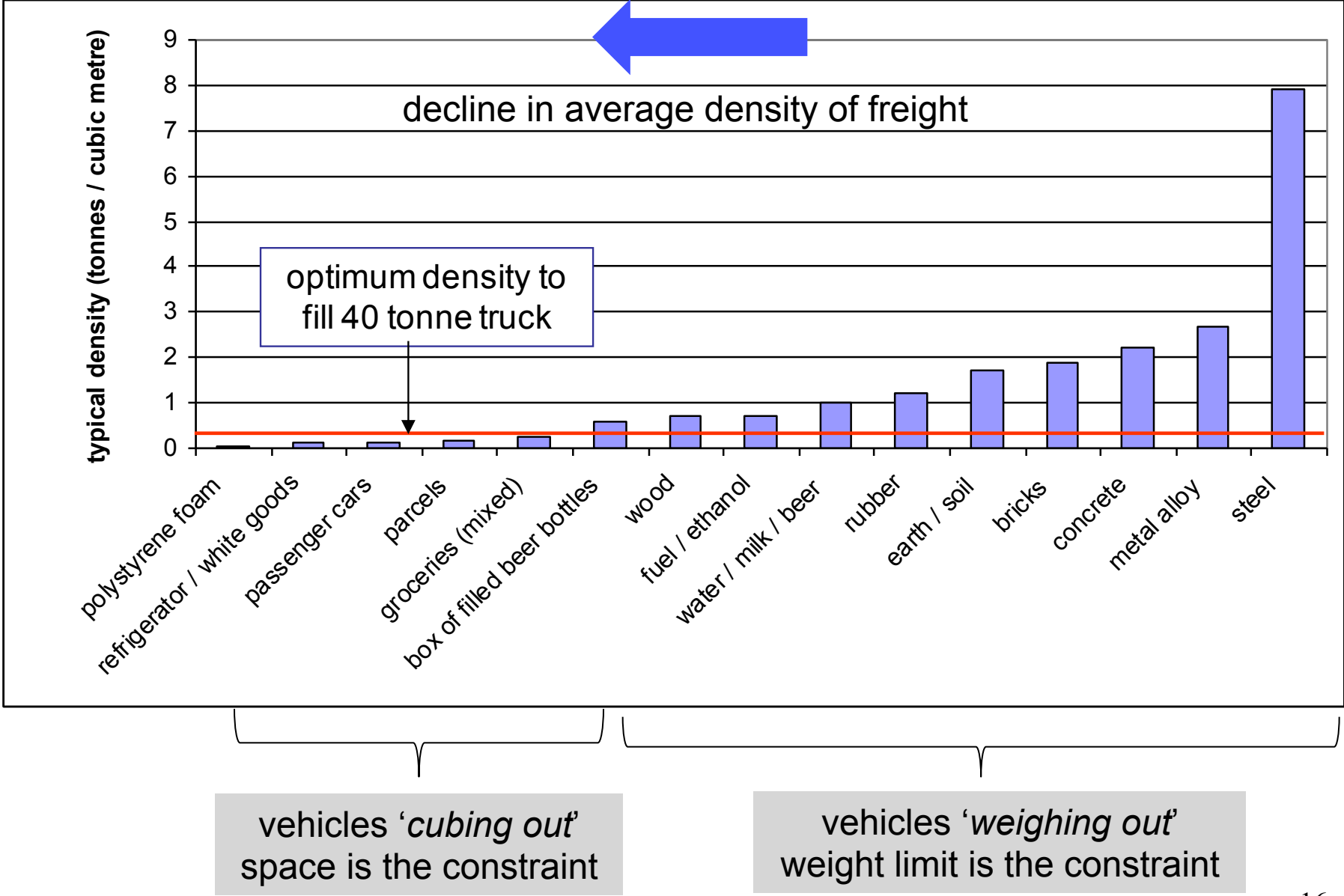
Online freight procurement: *a mature, well-established market in Europe and North America*

Increased functionality of web platforms: *inclusion of optimisers*

Diversification of UBER into the freight market (UBER Cargo)



Freight Density and the Utilization of Vehicle Carrying Capacity



Constraints on Truck Utilisation

Logistical cost trade-offs

Companies can be behaving perfectly rationally when they under-load their vehicles.

Making rational trade-offs between transport utilisation and:

- *inventory levels*
- *efficiency of warehousing and materials handling operations*
- *level of customer service - speed of delivery, order size etc.*

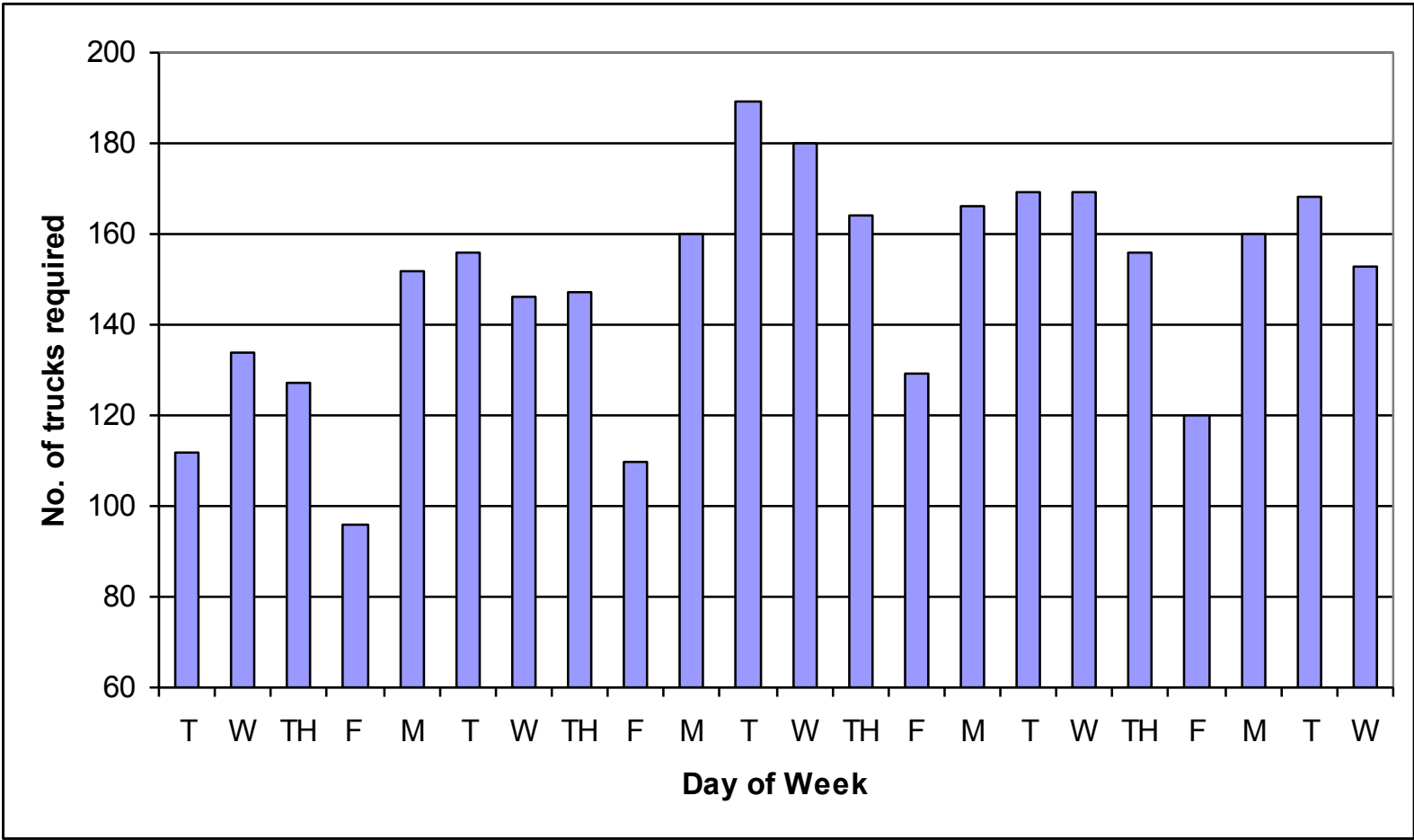
Minimising logistics costs / maximising profitability overall

Constraints on Truck Utilisation

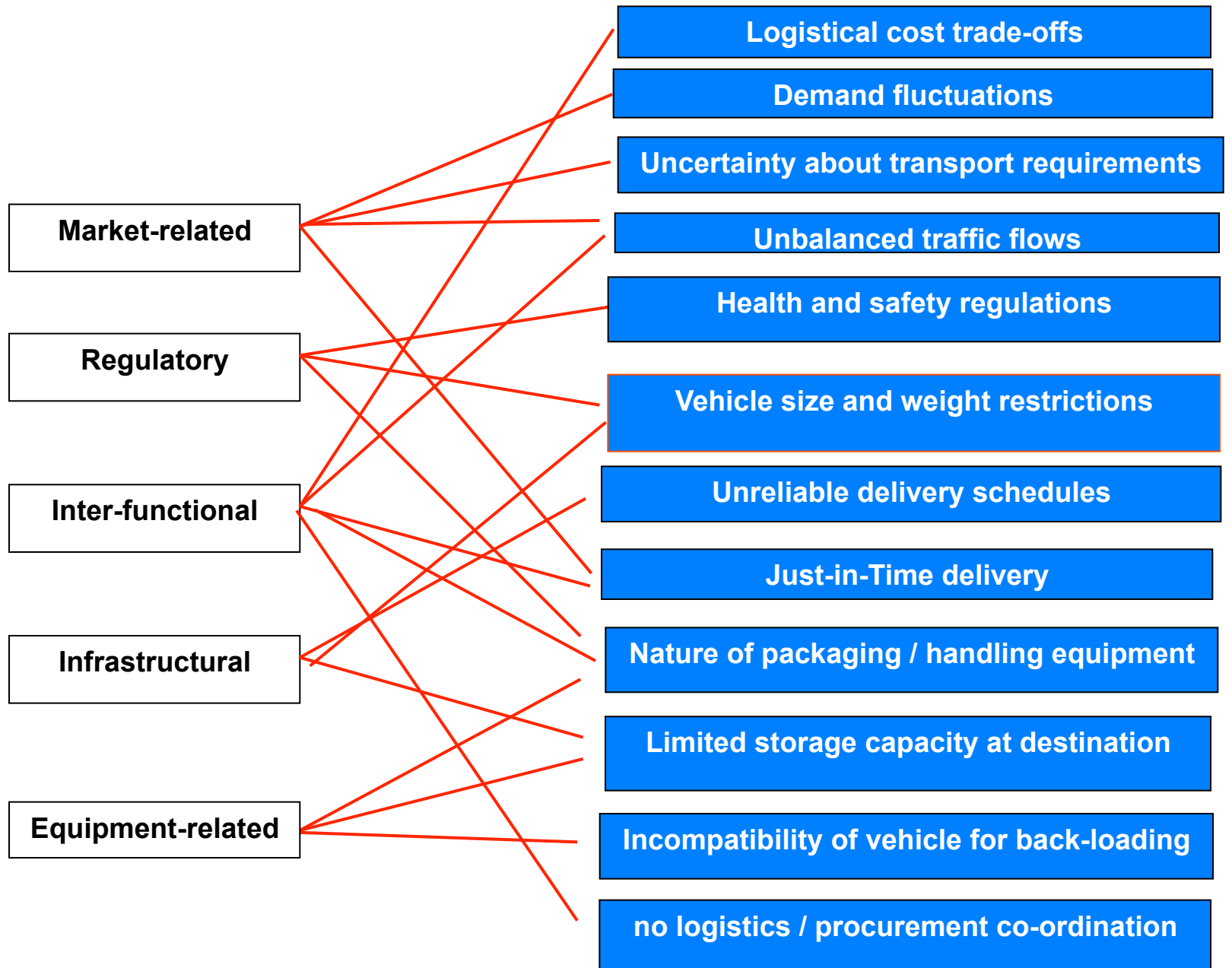
Logistical cost trade-offs

Demand fluctuations

Variations in the Daily Demand for Trucks Experienced by a Major Distributor of Steel Products

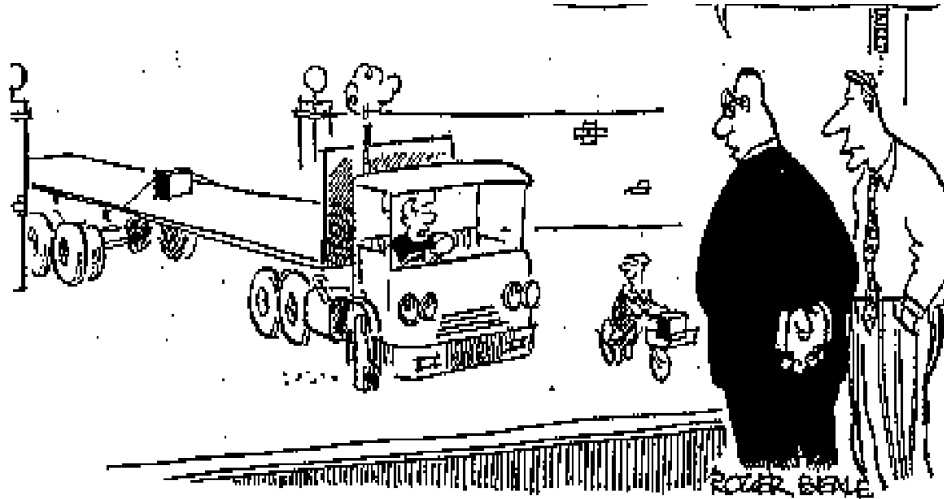


Constraints on Truck Utilisation



Should We Reverse the Just-in-Time Trend?

Some suppliers have adapted better than others to the disciplines of just-in-time delivery



Relaxing of JIT - an effective means of cutting carbon emissions?

Allowing more time to consolidate outbound loads and find backloads

More opportunity to switch to slower, less carbon-intensive transport modes

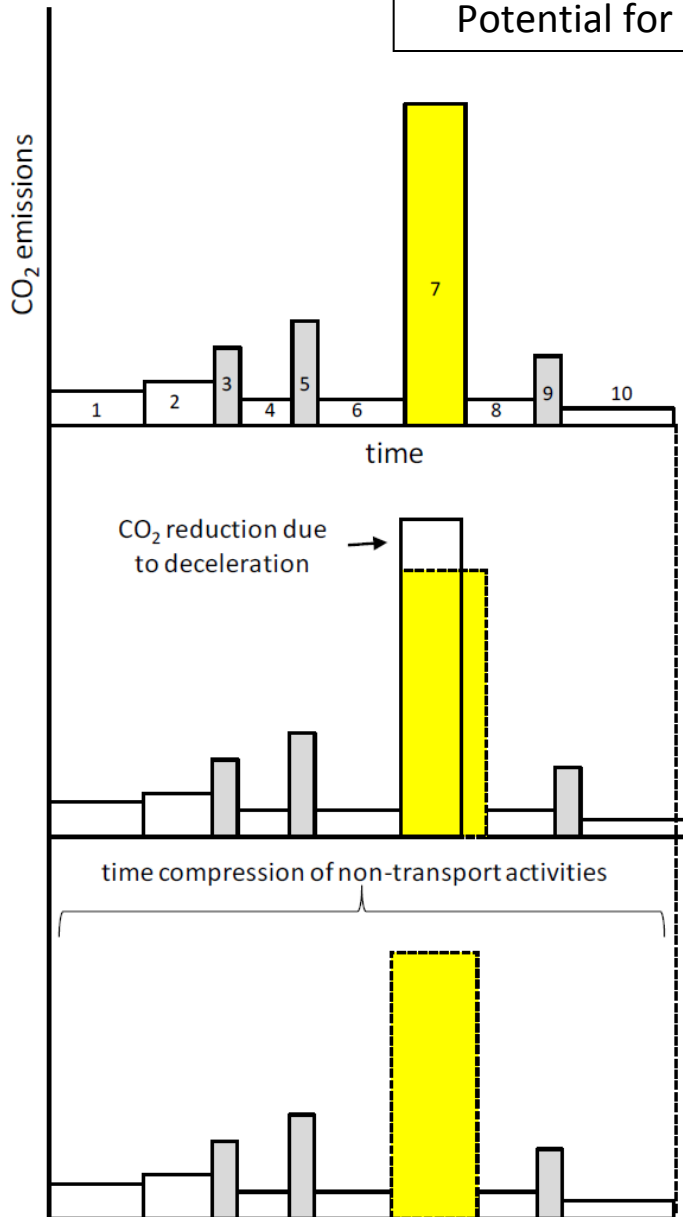
May cut transport-related CO₂ emissions, BUT....

Wider corporate CO₂ savings from JIT replenishment

Need comprehensive assessment of the CO₂ impact of JIT

Supply Chain Deceleration: *Heresy or Practical Suggestion?*

Potential for rescheduling supply chain processes to cut CO₂ emissions?



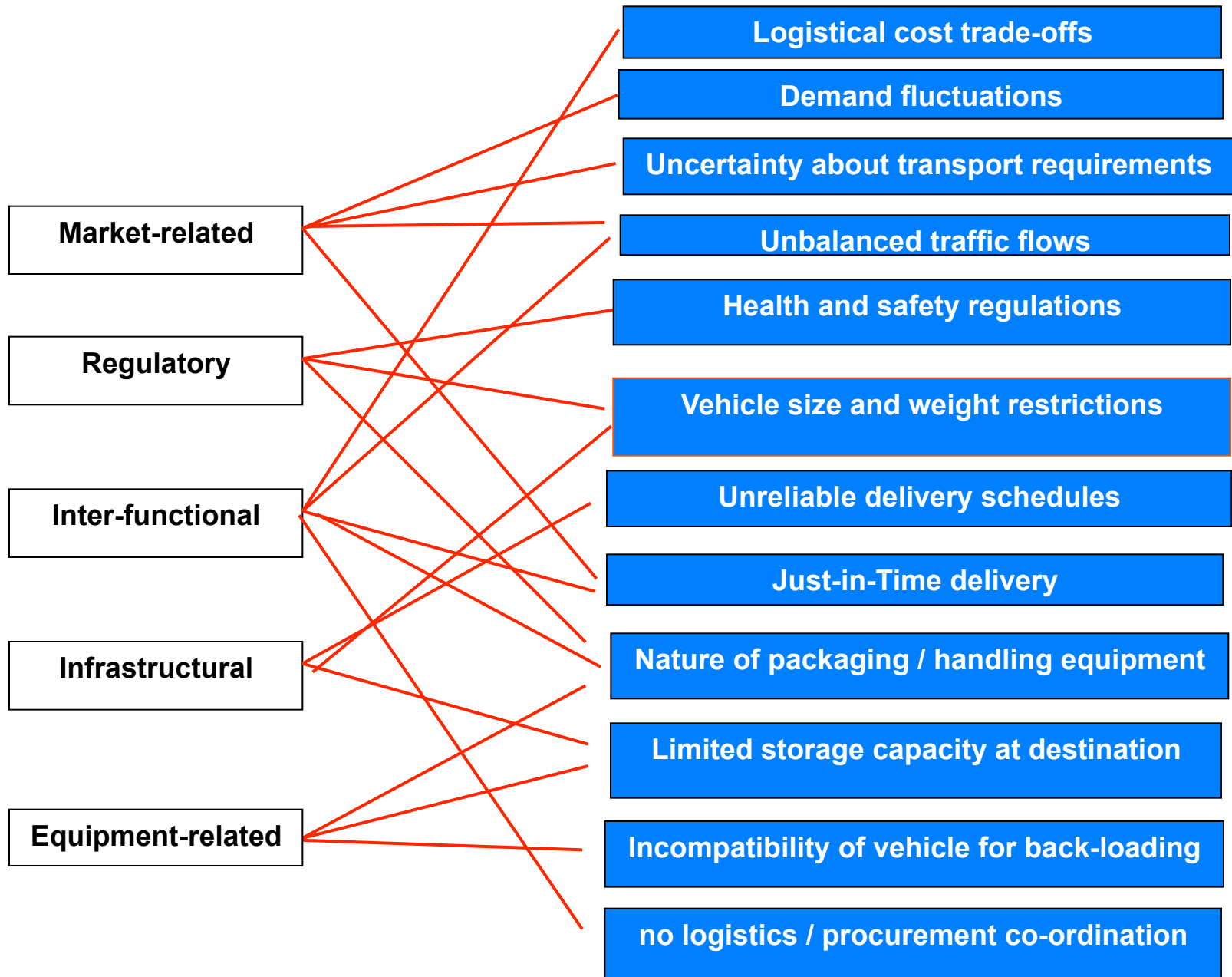
1. processing of inbound order
2. internal administration / checks
3. order picking
4. order awaiting loading
5. vehicle loading
6. vehicle waiting time
7. delivery
8. waiting time at reception point
9. vehicle off-loading and put-away
10. product storage prior to use / sale

- accelerate internal processes
- Internal time savings offset longer transit times
- net CO₂ saving within fixed order lead time

Freight Transport Deceleration: Its Possible Contribution to the Decarbonisation of Logistics

McKinnon (2016) *Transport Reviews*

Constraints on Truck Utilisation



Examples of Horizontal Logistical Collaboration between Shippers in Europe

Collaborating shippers	Sector	Geography
Pepsico and Nestle	FMCG	Benelux
Unilever and Kimberly Clark	FMCG	Netherlands
Nestlé and United Biscuits	FMCG	UK
Baxter, Colruyt, Eternit and Ontex	Healthcare, construction, wines & beverages, FMCG	Belgium-Spain
P&G and Tupperware	FMCG & household products	Belgium-Italy
Mars, United Biscuits, Saupiquet and Wrigley	FMCG	France
Tetley, Kellogg and Kimberly-Clark	FMCG	UK
JSP and Hammerwerk	Industrial equipment	Czech Republic
Spar and inbound suppliers	Retail chain, FMCG	Belgium

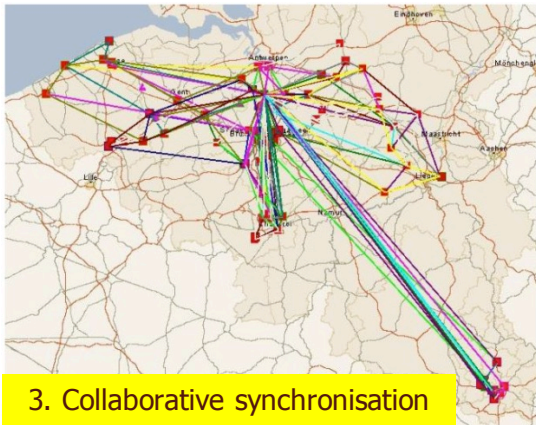
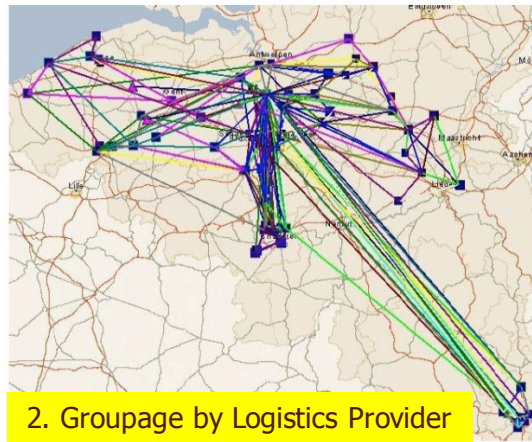
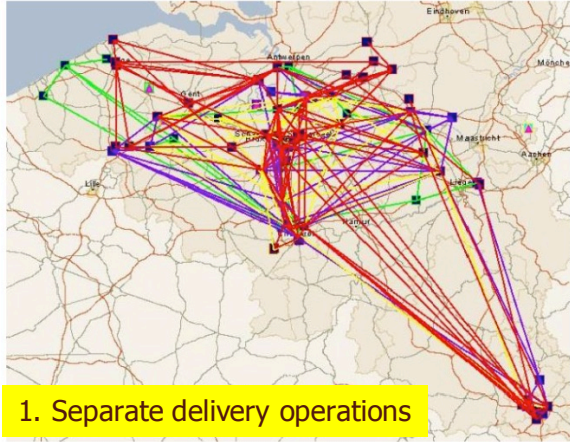
Source: McKinnon (2018)

Supply Chain Collaboration

Deep decarbonisation of freight transport will require much greater sharing of logistics assets

- change in the corporate mindset
- exhaustion of internal efficiency improvements
- confirmation of legality
- new IT tools support collaborative working

Nestle – PepsiCo Horizontal Collaboration in Benelux

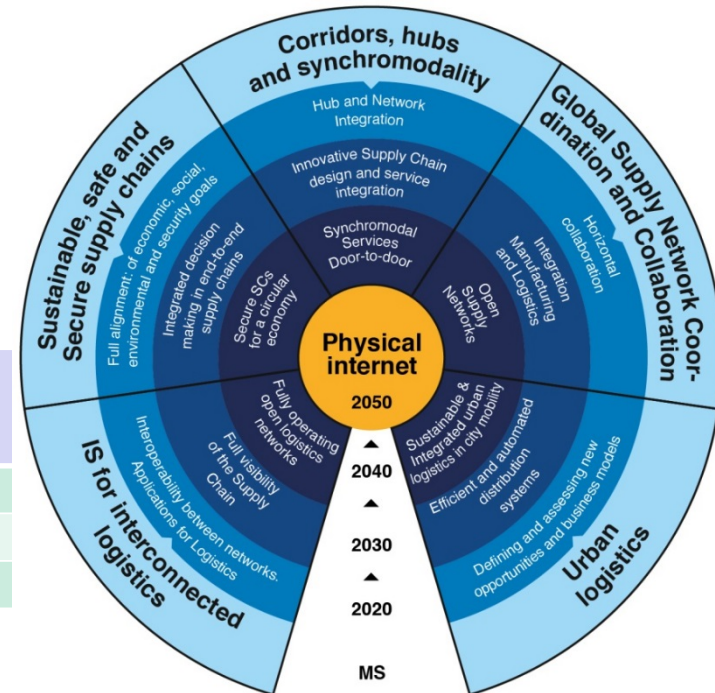


	Kg CO2 / tonne
1. Separate delivery	43.8
2. Groupage	27.3
3. Collaborative synchronisation	20.3

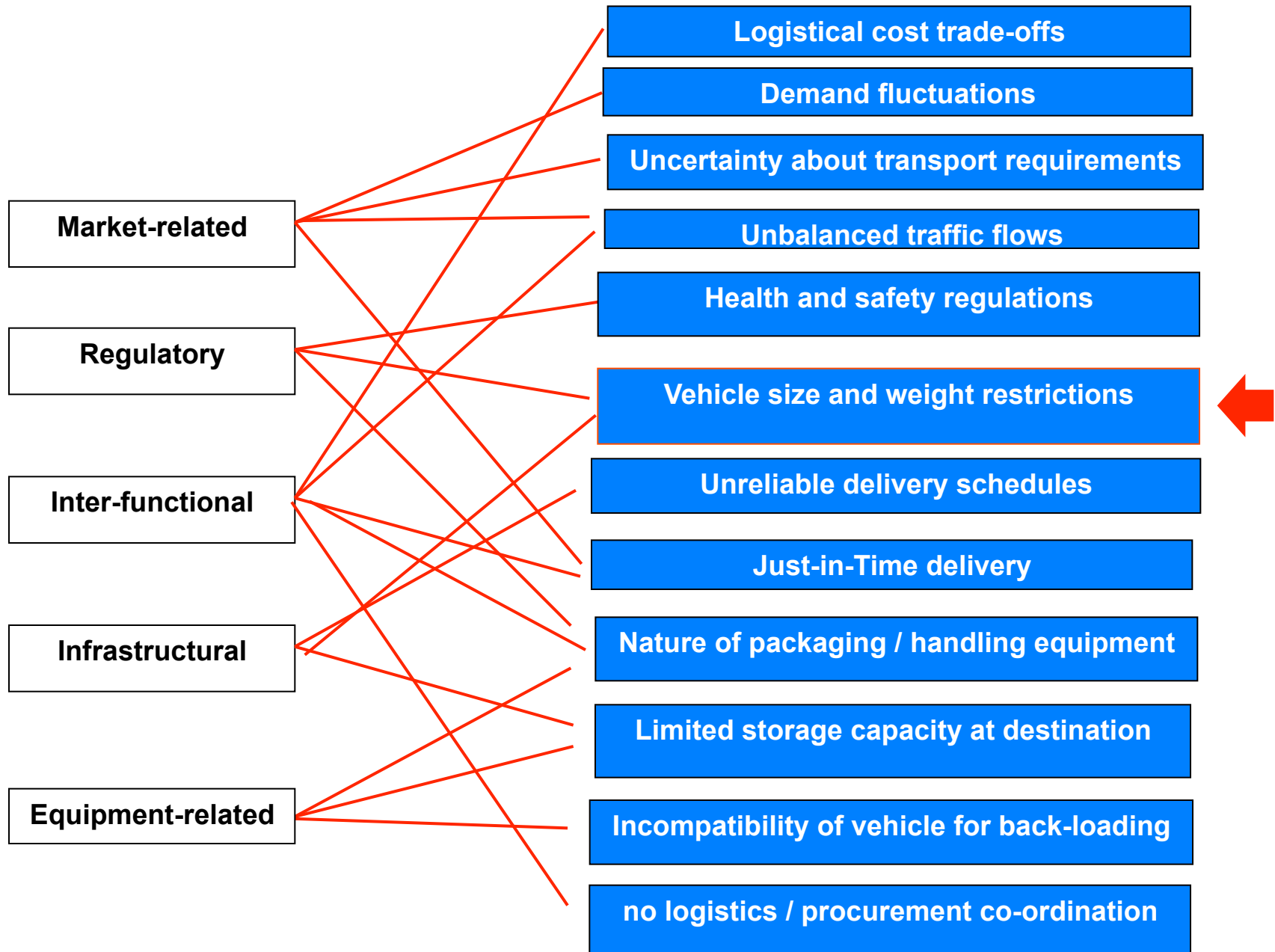
EU project: 

Source: Jacobs et al 2014

Long term contribution of the **Physical Internet** to logistics decarbonisation



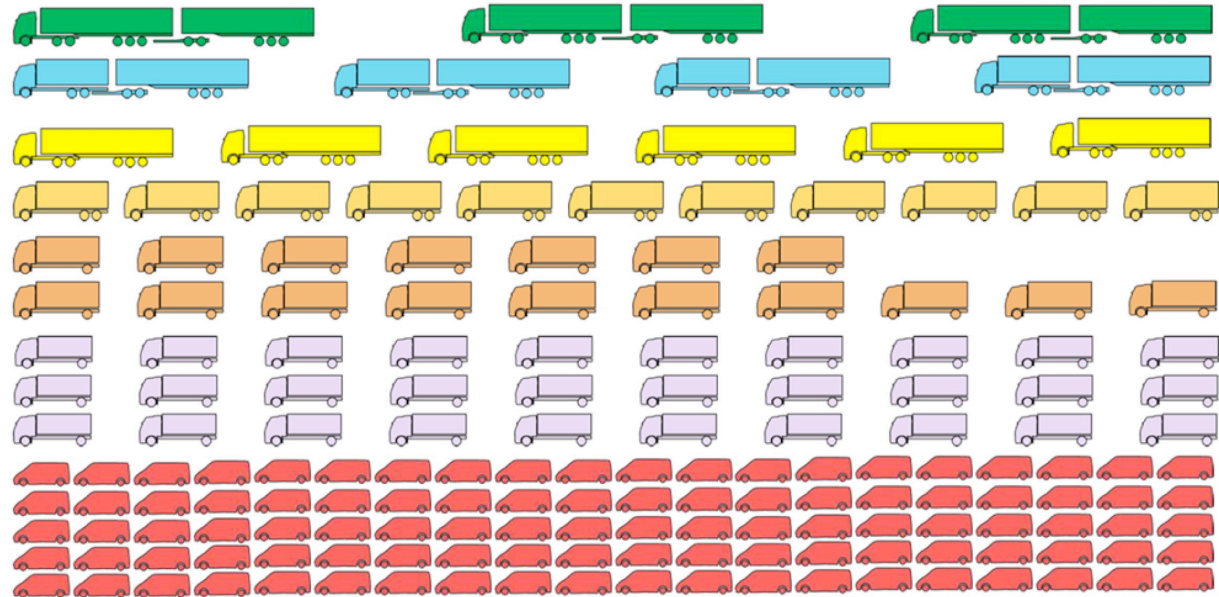
Constraints on Truck Utilisation



Environmental and Infrastructural Benefits of Consolidating Freight in Larger / Heavier Vehicles


Capacity needed to transport 200 pallets from Malmo to Gothenburg (600kg per pallet)

Trucks Drivers	Total space on road	Fuel	Fuel Index	CO ₂ / Pallet	Maximum authorized vehicle weight	EU driving licence
<i>No</i>	<i>meter</i>	<i>ml/tkm</i>	<i>40 t base</i>	<i>kg</i>	<i>tonnes</i>	<i>categorie</i>
3	294	14	72%	7	(76-90)	CE
4	364	15	80%	8	60	CE
6	492	19	100%	10	40	CE
11	836	28	150%	14	26	C
17	1275	34	180%	17	18	C
30	2220	47	250%	25	12	C1E
100	7100	94	500%	48	3,5	B



Source: Volvo Trucks, 2019

HCT in Europe: a much-researched and very controversial subject



 DIRECTORATE-GENERAL FOR INTERNAL POLICIES
POLICY DEPARTMENT B
 STRUCTURAL AND COHESION POLICIES


Agriculture and Rural Development
 Culture and Education
 Fisheries
 Regional Development
Transport and Tourism



A REVIEW OF MEGATRUCKS

STUDY




 Longer and Heavier Vehicles in practice



MOVING FREIGHT WITH BETTER TRUCKS

Summary Document







Long-Term Climate Impacts of the Introduction of Mega-Trucks

Study for the Community of European Railway and Infrastructure Companies (CER)

Coordinated by:
 The Fraunhofer Institute for Systems and Innovation Research (ISI) - Study coordination
 The Fraunhofer-Work Group for Technologies in Logistics Services
 The Fraunhofer Institute for Logistics and Material Flow (IME)
 TRT - Transport e-Traffic
 NESTEAR


Karlsruhe, May 12th 2009




Impact Assessment: High Capacity Vehicles

Business, Operations, Supply Chain & Transport Research Group
 D.Z. Leach & C.J. Savage
 University of Huddersfield




Inspiring Tomorrow's Professionals



 Published Project Report
 PPR205

Longer and/or Longer and Heavier Goods Vehicles (LHVs) – a Study of the Likely Effects if Permitted in the UK: Final Report

I thought
 W Newton
 Prof A McLennan (Heriot-Watt University)
 et al.



FINAL REPORT


Effects of adapting the rules on weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC

European Commission
 Directorate-General for Transport and Infrastructure
 Unit Logistics, Operation & Co-ordination
 10517
 10518 Brussels
 Belgium
 4 November 2008



 Your life in integrated analysis?







 VTI report 544:2007
 Published 2007

Impact of higher road vehicle dimensions on modal split

An ex-post analysis for Sweden

Inge Vieth
 Samuel Lindgren
 Hanna Lindgren









Longer and Heavier Vehicles

An overview of technical aspects

Gulstaime Laskov







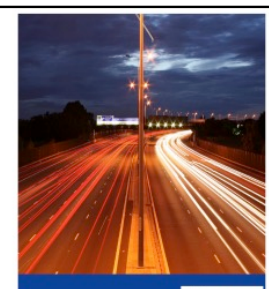
Longer Semi-trailer Feasibility Study and Impact Assessment

Final Summary Report

Department for Transport

December 2011



Transportation Research Part D: Transport and Environment
 Volume 40, October 2015, Pages 114–131

The longer and heavier vehicle debate: A review of empirical evidence from Germany

Vasco Sanchez-Rodriguez^{a, *}, Maja Piatek^{a, *}, Robert Mason^{a, *}, Tim Boenders^{a, *}

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<https://doi.org/10.1016/j.trd.2015.08.003>

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Article
Vehicle Weight, Modal Split, and Emissions—An Ex-Post Analysis for Sweden

Inge Vieth^{a, *}, Samuel Lindgren^a and Hanna Lindgren^a
 Swedish National Road and Transport Research Institute, P.O. Box 50605, 102 15 Stockholm, Sweden;
 samuel.lindgren@vli.se (S.L.); hanna.lindgren@vli.se (H.L.)
 * Correspondence: inge.vieth@vli.se

Received: 27 April 2018; Accepted: 23 May 2018; Published: 25 May 2018

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Available online at www.sciencedirect.com
 ScienceDirect
 Transportation Research Procedia 1 (2014) 108 – 116

41st European Transport Conference 2013, ETC 2013, 30 September – 2 October 2013, Frankfurt, Germany
Effects of longer lorries and freight trains in an international corridor between Sweden and Germany

Inge Vieth^{a, *}, Rune Karlsson^a

^a Swedish National Road and Transport Research Institute, P.O. Box 50605, 102 15 Stockholm, Sweden
^{*} Corresponding author. E-mail: inge.vieth@vli.se





High Capacity Transport

Towards Efficient, Safe and Sustainable Road Freight



Are Longer and Heavier Vehicles (LHVs) Beneficial for Society? A Cost Benefit Analysis to Evaluate their Potential Implementation in Spain

A. ORTEGA, J.M. VASSALLO, A.F. GUZMÁN AND P.J. PÉREZ-MARTÍNEZ

Transportation Research Part D: Transport and Environment
 Volume 41, Part B, June 2018, Pages 459–470

Longer and heavier vehicles in Belgium: A threat for the intermodal sector?

Dries Haens^{a, *}, Tom van Lee^a, Cathy Mathers

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<https://doi.org/10.1016/j.trd.2018.08.007>

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Forecast of Transport Demand Effects of Longer Trucks in Germany

Robert Burg^{1, (C)}, Elisabeth Neumann¹, Jan-André Böhne², and Marco Irzik²

High Capacity Transport in Europe 2019

Norway
25.25 metre 60 tonnes

Sweden
25.25 metre 74 tonnes

Finland
34.5 metre 76 tonnes

Denmark:
25.25m 60 tonnes

Netherlands:
25.25m 60 tonne

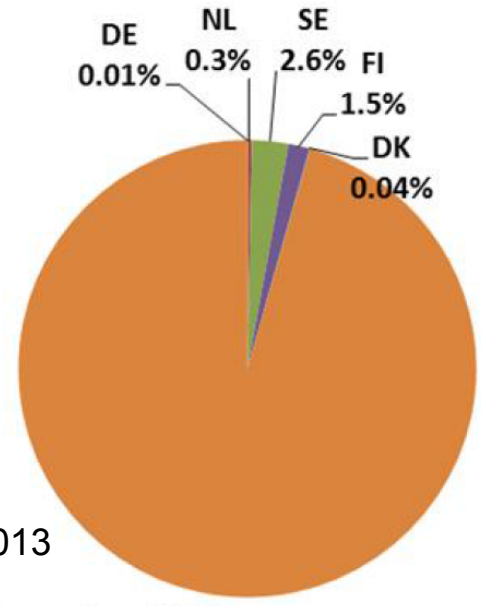
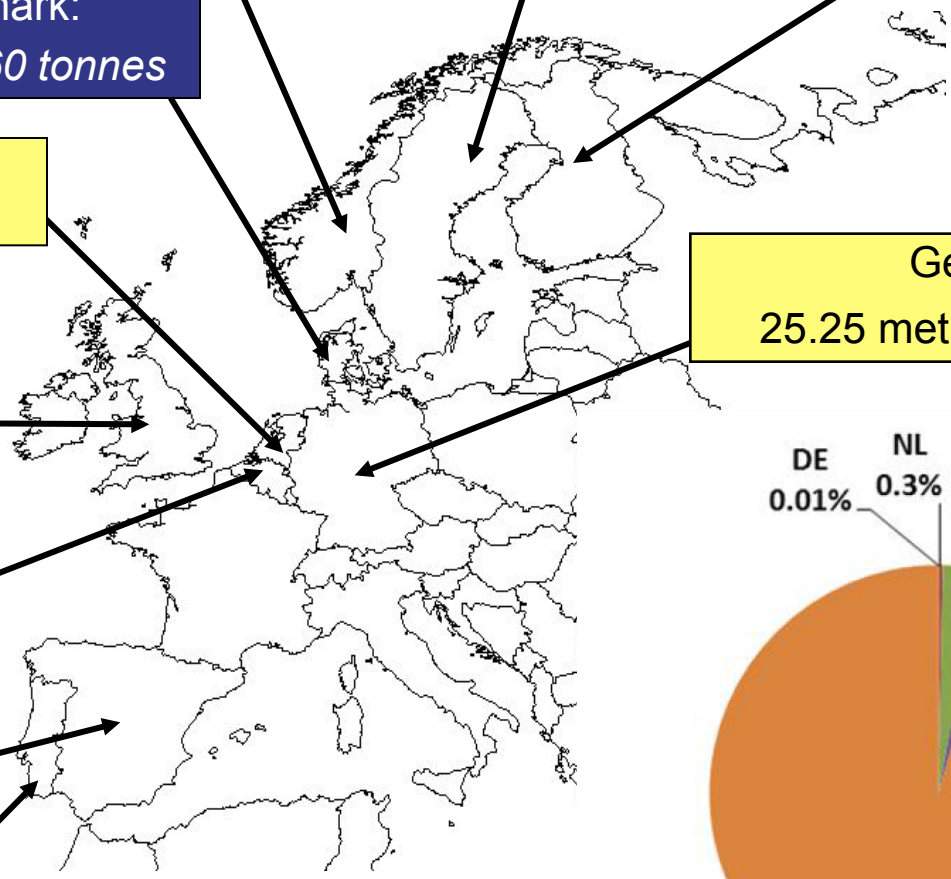
Germany:
25.25 metre 40/44 tonnes

UK:
trial of 1-2 m longer trailers
Extensive use of double-deck trailers

Flanders
HCT pilot project

Spain
25.25 metre 60 tonnes

Portugal
25.25 metre 60 tonnes

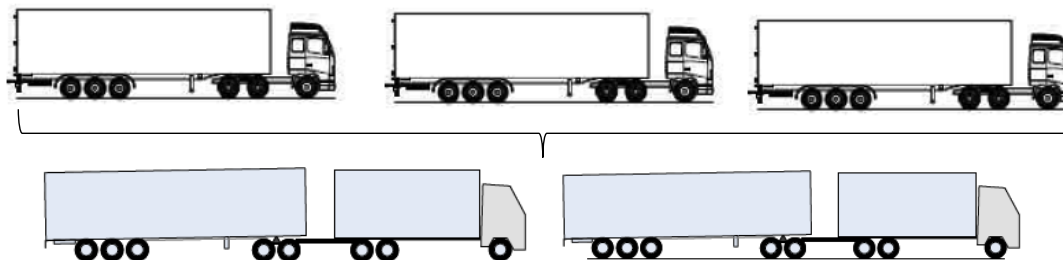


HCT 4.4% share of EU road tonne-kms in 2013

2019: 6-7%

Conventional LGV
95.58%

Potential contribution of HCT to road freight decarbonisation



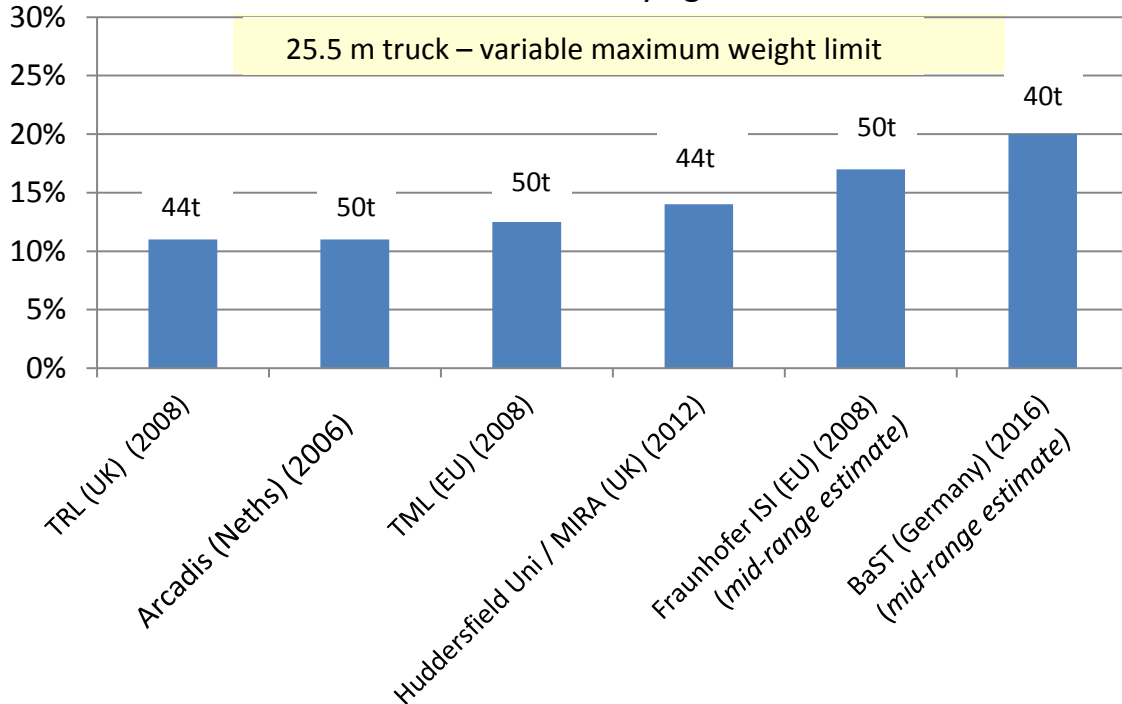
2 truck for 3 substitution: load consolidation → reduced energy use and emissions per tonne-km

vehicle level analysis



system level analysis

% reduction in carbon intensity against baseline vehicle



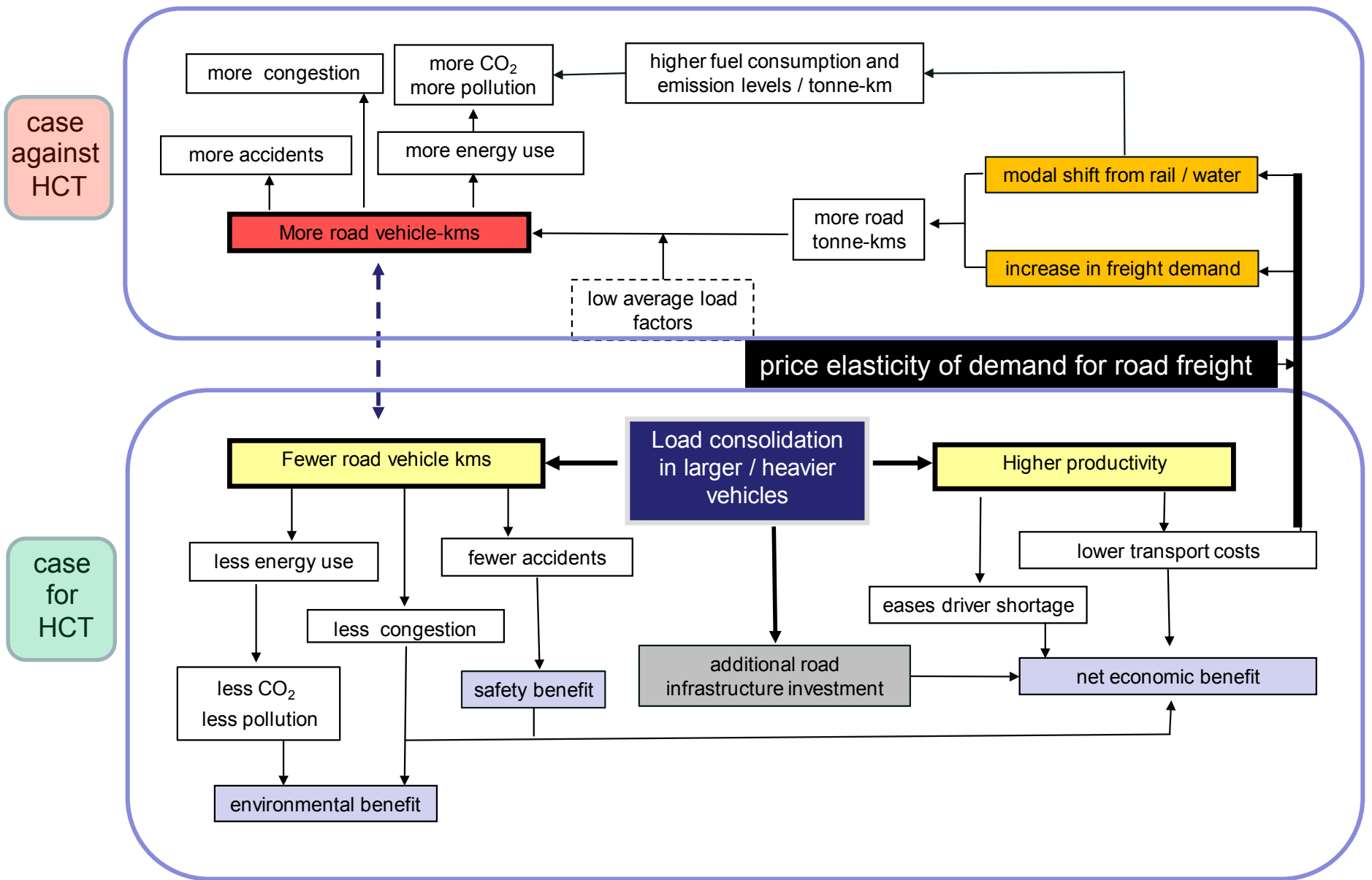
Net effect on CO₂ depends on:

- adoption rate of LHVs
- induced traffic
- circuitous routing
- load factor assumptions
- modal shift

freight modal shift
versus
road freight efficiency improvement

Conflict between core freight decarbonisation strategies

High capacity transport: *polarisation of the arguments for and against*



Increase energy efficiency

Improve Energy Efficiency in the Freight Transport Sector

vehicle technology: new build + retrofits

- upgraded drive-trains
- light-weighting
- low-rolling resistance tyres
- improved aerodynamics



Over cab spoiler



Teardrop



Cheetah



Boat-tails



Trailer under-tray



Dolphin

vehicle operation: IT, training, monitoring



eco-driver training



telematic monitoring



platooning



automation

fuel economy standards for new trucks:

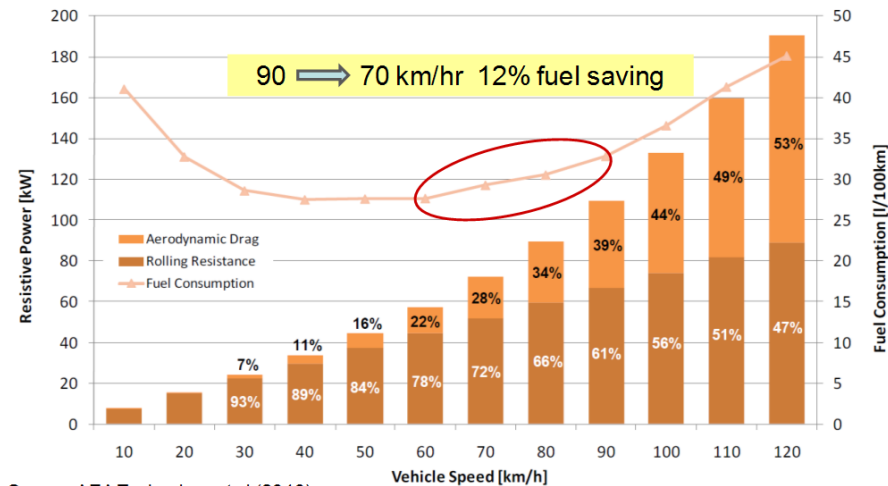
Fuel Economy Standards for Heavy Duty Vehicles

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Japan				Phase 1										Phase 2	
U.S.			Phase 1					Phase 2							
Canada			Phase 1					Phase 2							
China	Phase 1		Phase 2						Phase 3						
EU:	15% less CO ₂ by 2025 30% by 2030														
India										Phase 1					
Mexico										Phase 1					
S. Korea										Phase 1					

Hashed areas represent unconfirmed projections of the ICCT

Source: ICCT (2015)

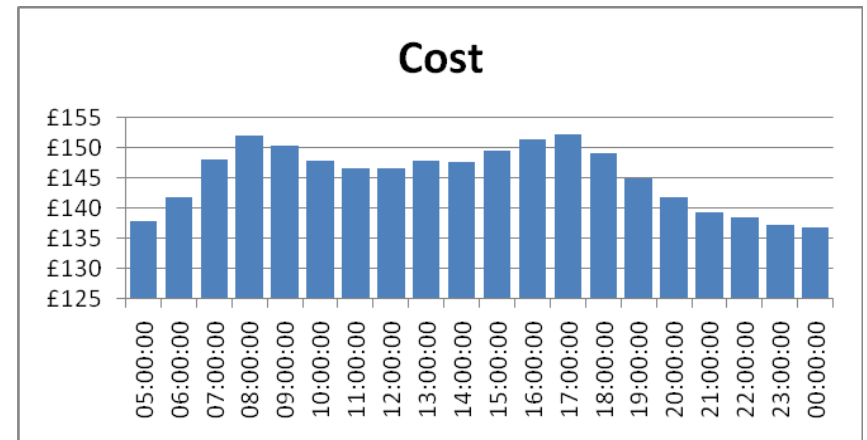
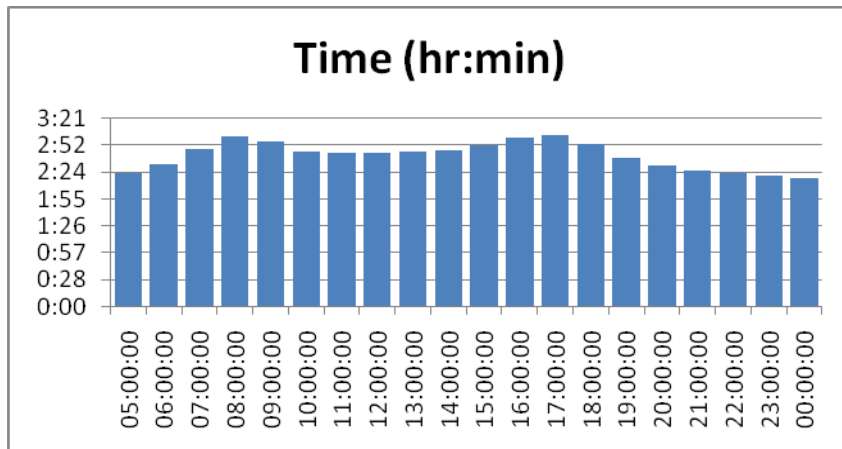
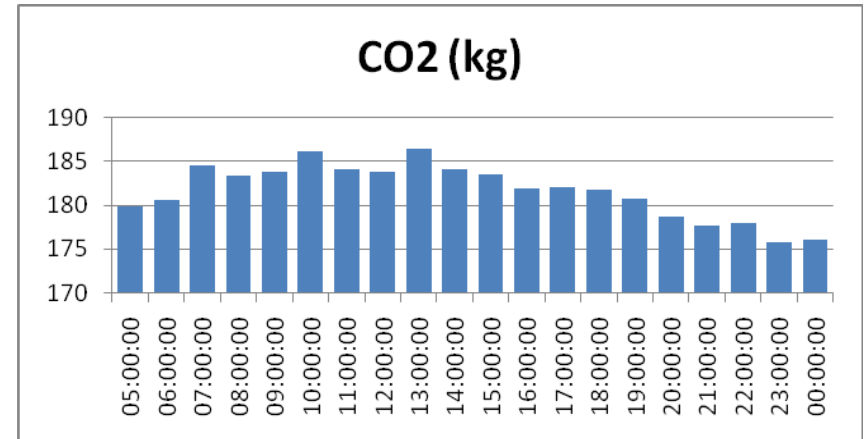
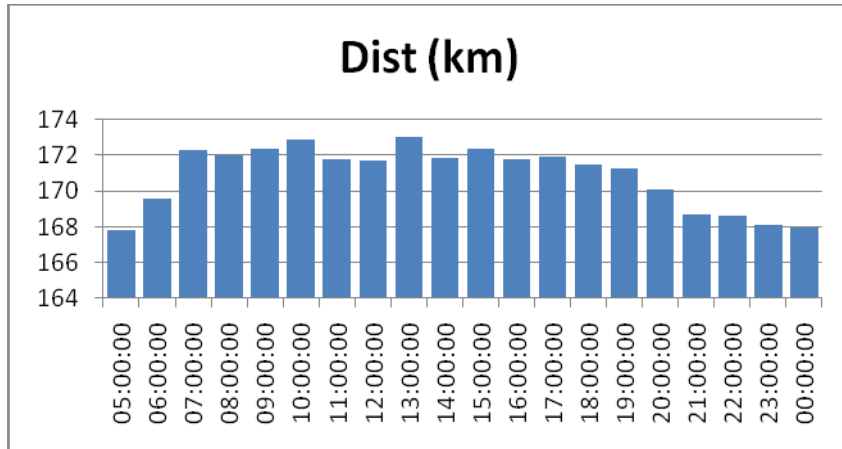
business practice: e.g. deceleration



Source: AEA Technology et al (2010)

Effects of Varying Start Times for Long Haul Road Deliveries Network

Simulation modelling of truck trips across UK trunk road network



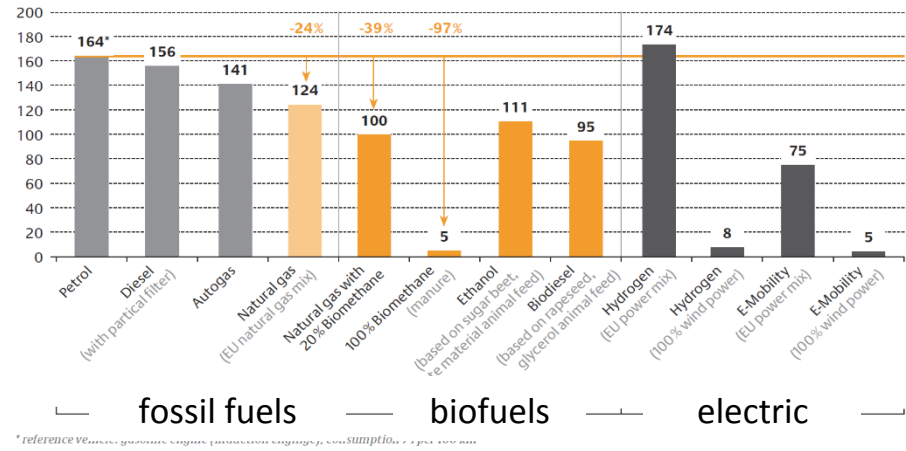
Source: Palmer and Piecyk, 2010

constraints on the rescheduling of deliveries to minimize congestion

Switch to low carbon energy

Switch to Cleaner, Low Carbon Energy

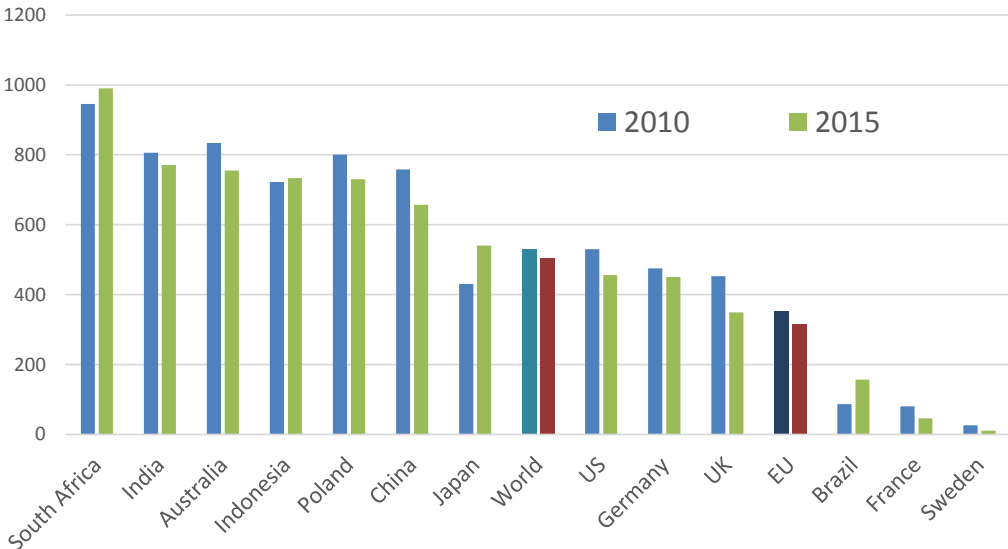
WTW CO_{2e} emissions



biofuel fuels: *slow uptake*

- uncertainty about net GHG impact
- limited supply of sustainable biofuels
- lack of refuelling infrastructure for gas
- ‘methane slip’ problem

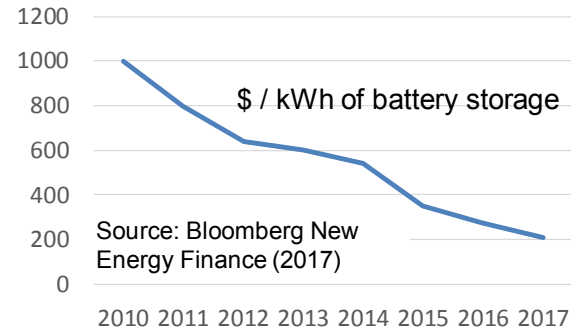
decarbonisation by electrification



Carbon intensity of electricity generation (gCO₂ / kWh)

Source: McKinnon, 2018

battery-powered road freight



Local delivery operations

- recharging infrastructure
- future battery performance
- E- vehicle price differential



Long haul operations

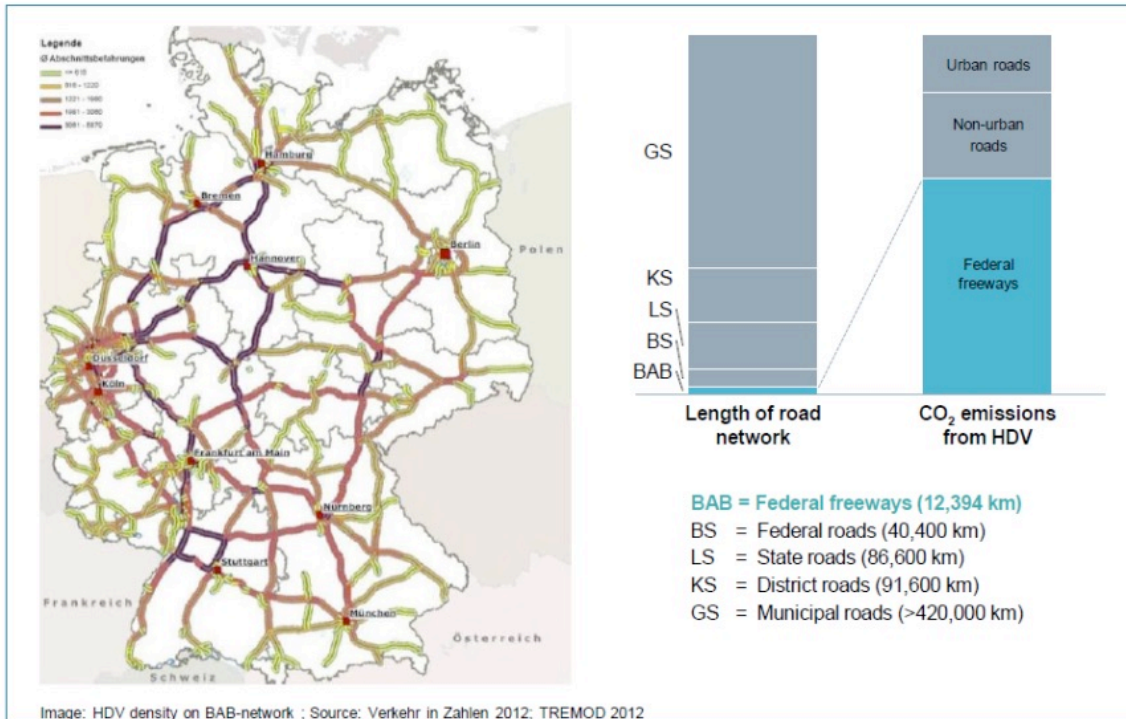


Tesla Semi a gamechanger?

- battery weight & size?
- max payload?
- cost?

Highway electrification: *the e-Highway*

electrified roads: *Trials in Sweden, Germany and the US*



The analysis of the German road network leads to the following key messages:

- 1 **60%** of the HDV emissions occur on 2% of the road network (BAB = 12,394 km)
 - 2 **89 %** of German truck trips after leaving the highway are **50 km or less**
- Source: [BMVI website](#). Study available [here](#)

BDI / Boston Consulting Group / Prognos study:

Source: Siemens

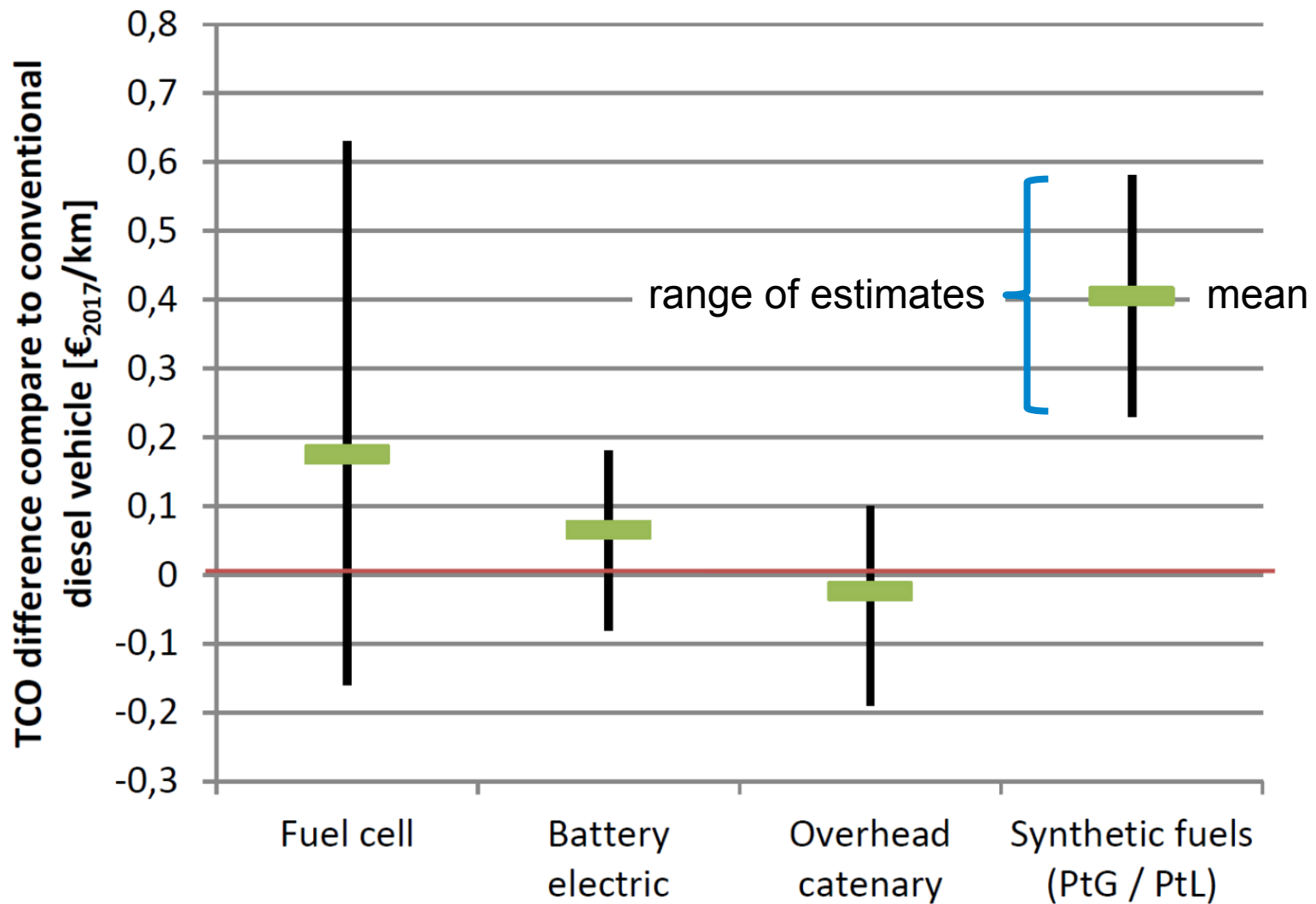
Recommends that 4000-8000 km of German autobahn network be electrified

Capital cost of highway electrification: €1.1 – 2.5 million per km (TML, 2017).

25,000 km of EU motorway: €30-65 bn + €5 bn annual maintenance (Fraunhofer IBP et al, 2015)

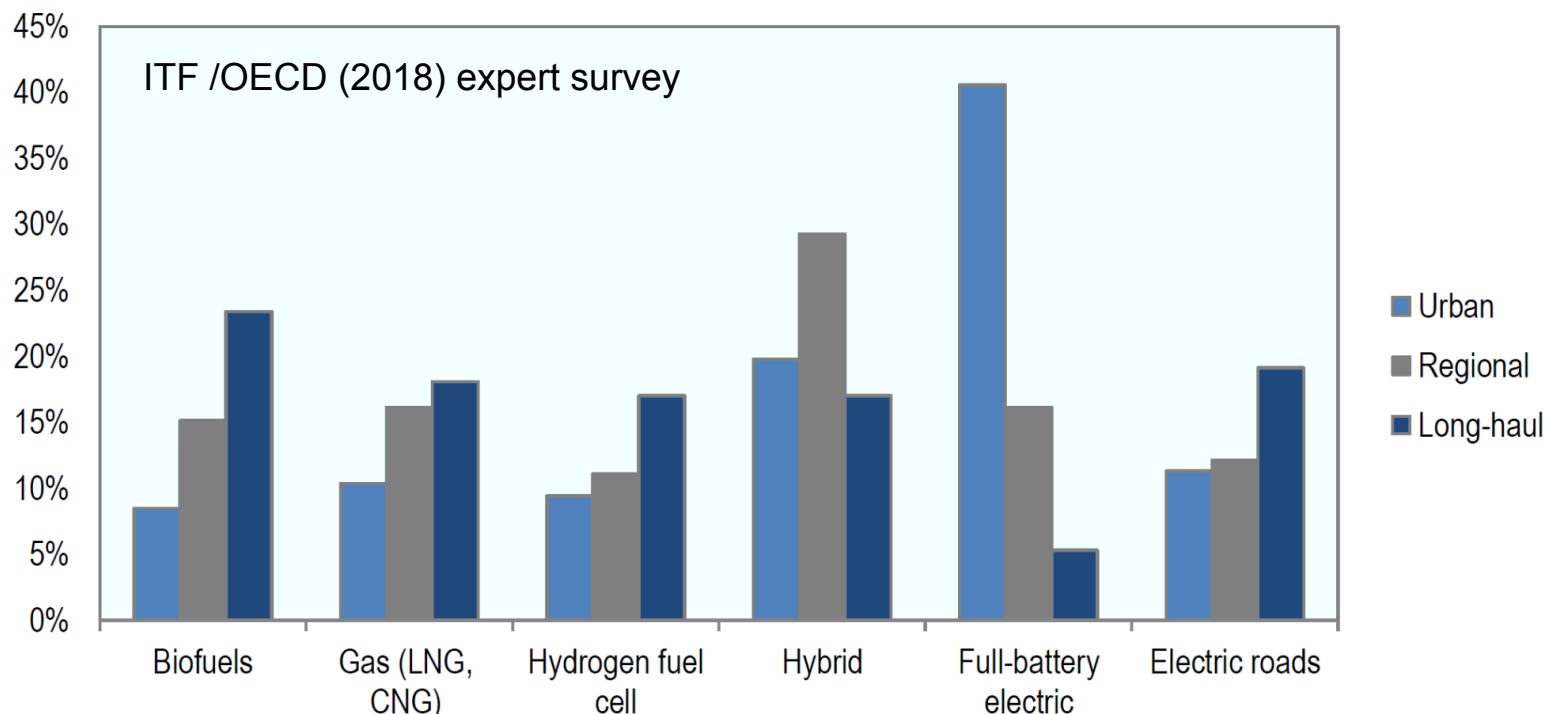
Alternative drive trains and energy sources for long haul road freight

Variation in total cost of ownership relative to fossil diesel vehicles over period 2020=2030



Disagreement over most cost-effective energy decarbonisation pathway for trucking

What are the most cost-effective alternative energies for each type of road freight operation?



weight, size, recharging time and cost of long haul truck batteries

Sripad & Visvanathan (2017)

16 tonne Li-ion battery for 960 km range

Energy Transitions Commission (2018)

3.4 tonnes battery for 700 km range

practicality and cost-effectiveness of hydrogen fuel cells in HDVs

Pye et al (2015), Energy Transitions Commission

despite high energy losses, potentially viable decarbonisation option

Bossel (2004), Cebon (2018)

energy losses so high never likely to be viable option

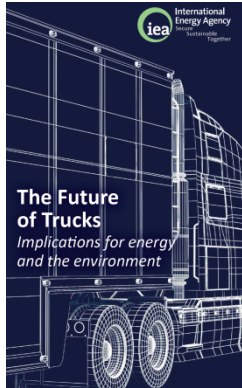
<https://bit.ly/2tc20uc>

<https://bit.ly/2BoQQGN>

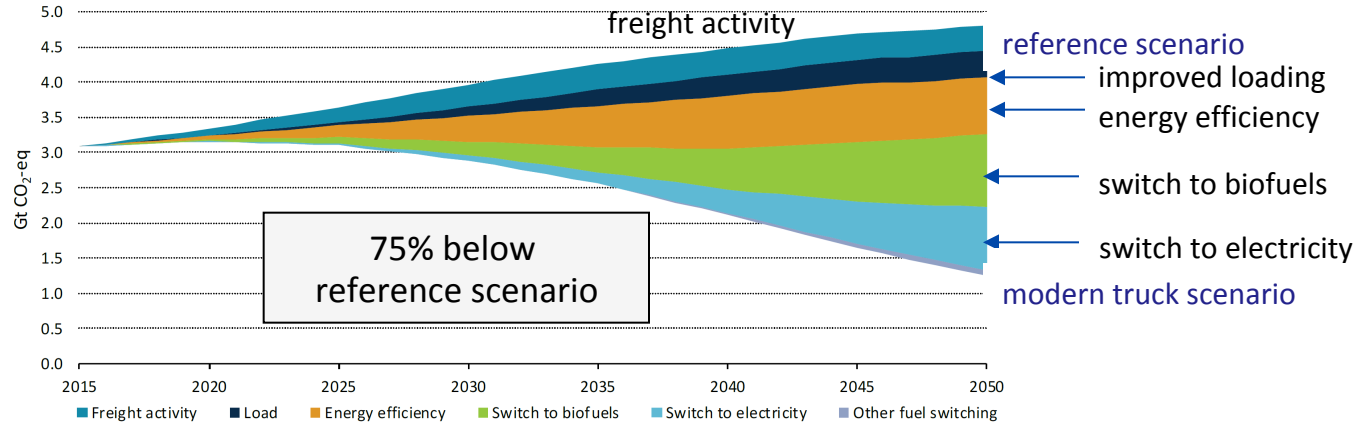
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Assessing Carbon Savings from Efficiency Improvements and Switch to Alternative Energy

CO_{2e} emissions from road freight transport: reference (i.e. baseline) scenario vs modern truck (i.e. low carbon) scenario

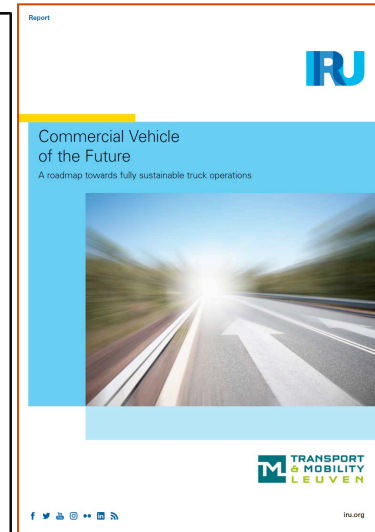


source: IEA (2017)





IRU (2017) 'Commercial Vehicle of the Future'

Long haul	2030	2050	Comment	cumulative reduction 2030	cumulative reduction 2050
Powertrain efficiency (diesel)	10%	15%	Includes engine, transmission, auxiliaries,...	10.0%	15.0%
Gas vehicles	2%	4%	Minimise methane emissions	11.8%	18.4%
Renewable fuels (gas & liquid)	2%	24%	IEA general target, large increase in 2nd generation biofuels needed. Includes biogas.	13.6%	38.2%
Driver training and driver assistance systems	6%	8%	Includes ACC, PCC,...	18.8%	43.2%
Reduce max speed	2%	2%	To 80 km/h	20.4%	62.8%
ITS & communications	1%	4%	Platooning	21.2%	46.5%
Aerodynamics	6%	10%	Important contribution expected from trailers and semi-trailers, including solutions developed in the TRANSFORMERS Project	25.9%	51.3%
Tyres	7.5%	12.5%	Includes super singles	31.5%	57.4%
Lightweighting	0%	0%	Compensated by increased weight from other measures	31.5%	57.4%
Pavement	3%	3%	Improved rolling resistance (maintenance or new pavement)	33.5%	58.7%
Reduce empty running, improve load factors, digitalisation	2%	10%	Rollout of coordinated system needed	34.8%	62.8%
More flexibility in weights and dimensions (including EMS)	3.5%	7.5%	Allowance of EMS in cross border transport in the EU	37.1%	65.6%
More renewables – hybridisation (2030)/electrification (2050) ??????	3%	37%	For 2050, most from full electrification ????????	39.0%	78.2%

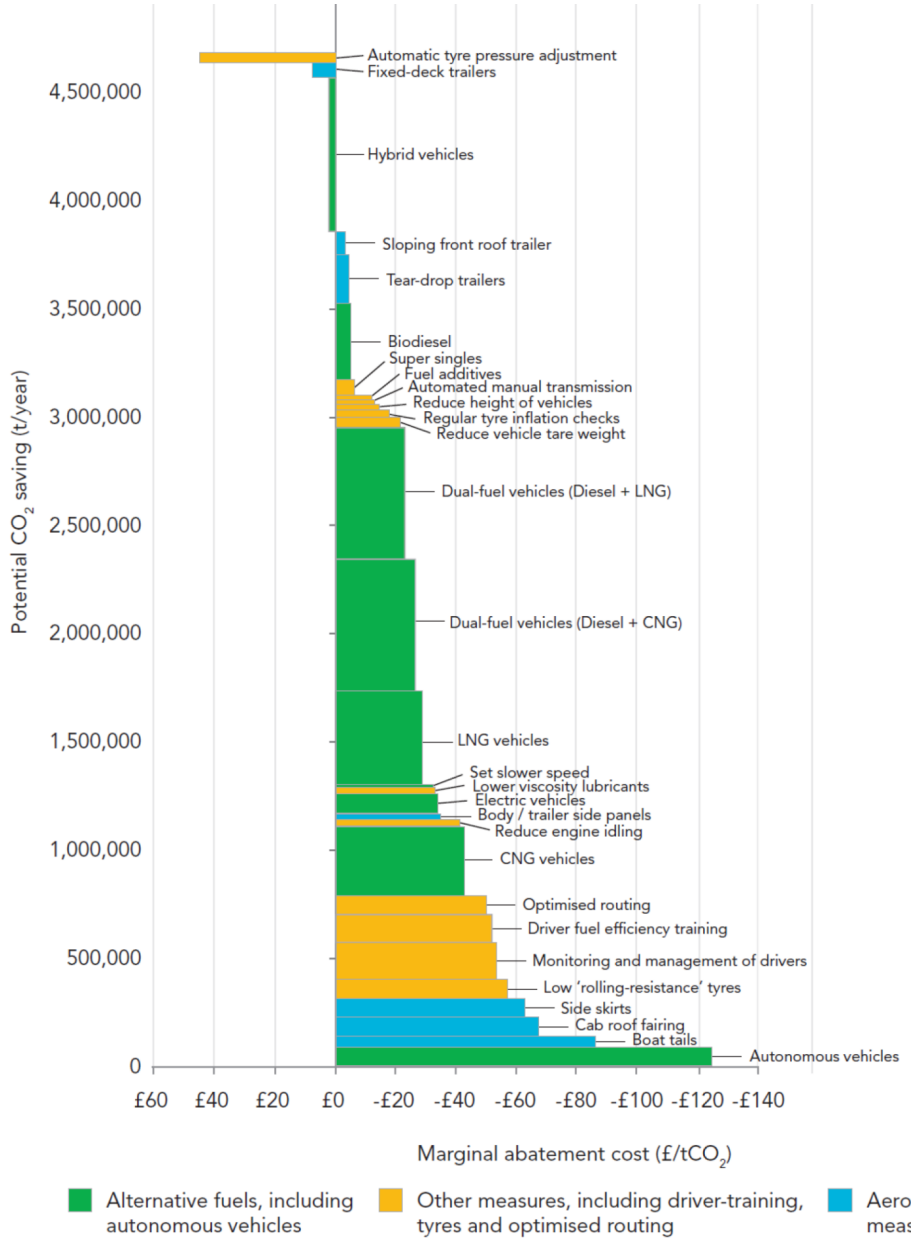


Marginal Abatement Cost (MAC) analysis for decarbonisation of articulated trucks in the UK by 2040


 Government Office for Science
 

Decarbonising road freight

Future of Mobility: Evidence Review
 Foresight, Government Office for Science



Sustainable Road Freight (SRF) Optimiser

SRF Optimiser by SRF

HERIOT WATT UNIVERSITY | UNIVERSITY OF CAMBRIDGE | EPSRC | VCL VALUE CHAIN LAB

Data Input | **Reporting** | **Calculator**

Fuel Cost Input
 Diesel (litre) £1.17 | Electric (kWh) £0.13
 Bio diesel (litre) £1.05 | CNG (kg) £0.85
 LNG (kg) £0.92

Macro Input
 Discount rate 10.0% | Period 2015
 Carbon targets 2.5%

Selected saving measures summary
 Annual savings

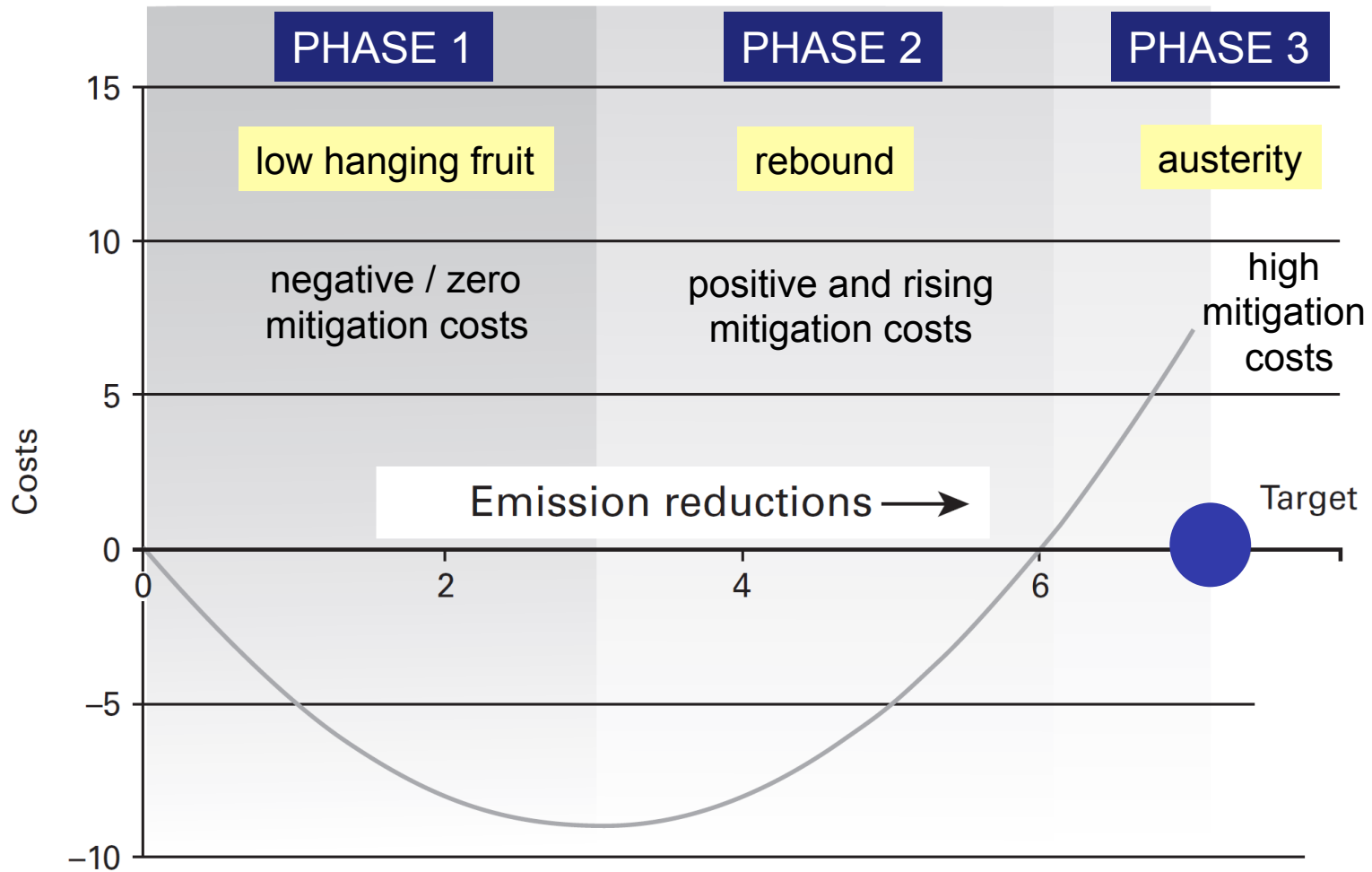
#	Carbon-saving Measures	Net Present Value (£)	Cost Savings per annum (£)	CO ₂ Savings per annum (KgCO ₂)	Fuel Saved (Litres)	Payback period (Years)	Include intervention	Advanced Tuning
(14) 3.5 tonne to 7.5 tonne rigid								
26	Monitor and manage driver fuel performance (including use of telematics)	£1.2K	£533.8	1.2K	456.2	1.1	<input checked="" type="checkbox"/>	
27	Give drivers training in fuel efficiency	£1.1K	£533.8	1.2K	456.2	0.6	<input type="checkbox"/>	
28	Increase the proportion of off-peak, evening and night-time deliveries	£577.5	£118.6	261.9	101.4	0.0	<input type="checkbox"/>	
29	More regular tyre inflation checks	£462.0	£94.9	209.5	81.1	0.0	<input type="checkbox"/>	
30	Use telematics to optimise vehicle routing	£456.5	£296.5	654.8	253.5	2.4	<input type="checkbox"/>	
31	Increase use of biodiesel vehicles	£265.2	£54.5	1.3K	0.0	0.0	<input type="checkbox"/>	

Summary Table:

Cost saving current yr, in £'K	£12.3K
Cost saving over 3 yrs, in £'K	£37.1K
Fuel saving, in K liters	10.4K
Energy saving, in K kWh	104K
Reduction in CO ₂ , in K Kg	30.4K

<http://www.csrf.ac.uk/srf-optimiser-2/>

3 Phases in the Economics of Logistics Decarbonisation



Adapted from Tavasszy (2014)

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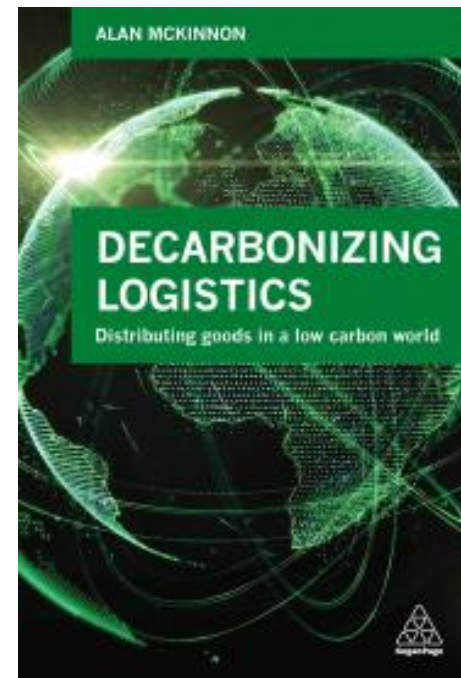
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<https://www.koganpage.com/product/decarbonising-logistics-9780749483807>