

Green Logistics: Challenges for Management Science

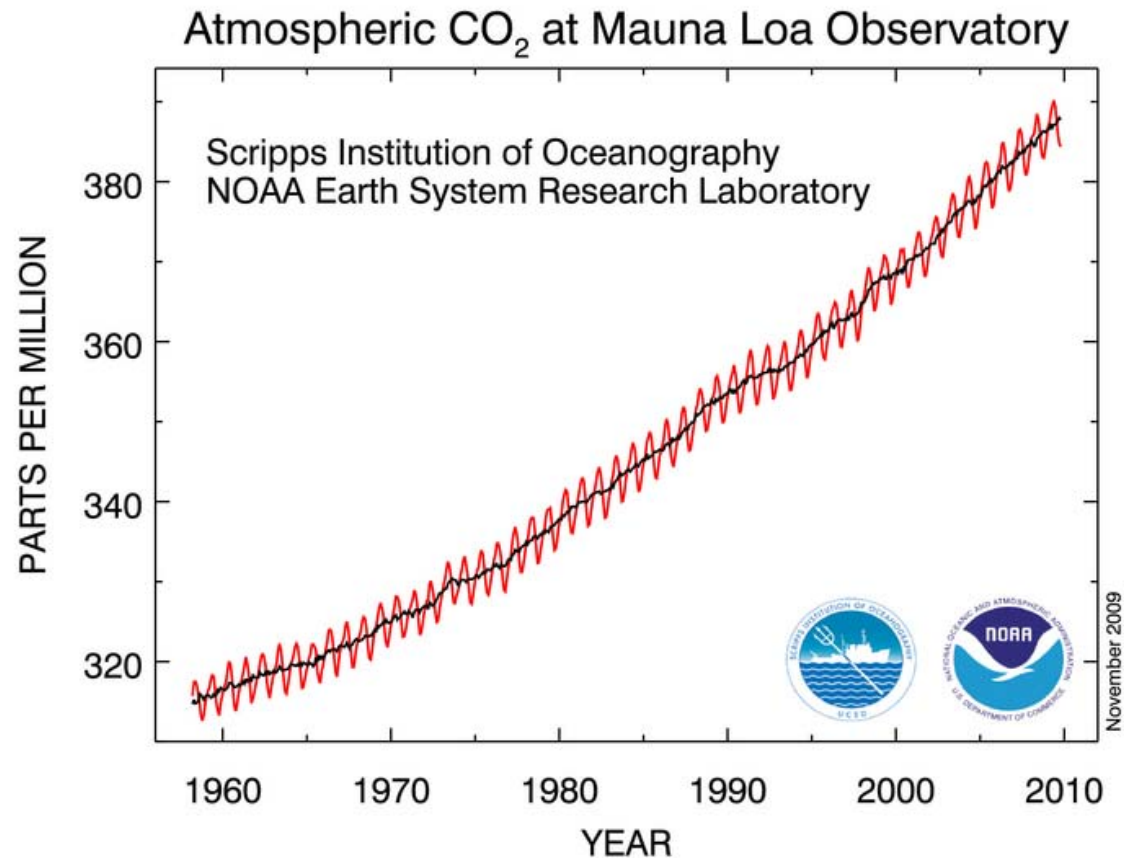
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Change in atmospheric CO₂



Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii
Source: National Oceanic and Atmospheric Administration, accessed November

2009 at: http://www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html



Lancaster University
MANAGEMENT SCHOOL

The climate change debate

Gradual warming: sea level rise, increasing drought, declining agricultural yields, land becoming uninhabitable, more severe storm damage, loss of biodiversity / extinction of species

Crossing ecological tipping points:

- Warming of tropical rain forest: *switch from CO₂ sink to source*
- Melting of Arctic / Antarctic / Greenland ice-sheets: *sea-level rises by several metres*
- Thawing of the Siberian tundra – *release of methane*



Source:
McKinnon, 2008

Green Agenda Issues

- To keep the increase in global temperature by 2100 within 1- 2°C it is estimated that CO₂ must be restricted to 450 ppm.
- Governments are introducing carbon reduction targets and policies.

Green Logistics Project

- A research programme into the sustainability of logistics systems and supply chains
- A consortium of 6 UK universities
- Funded by EPSRC for 4 years (2006-2010)
- Supported and steered by a range of organisations including the Department for Transport and Transport for London

Website



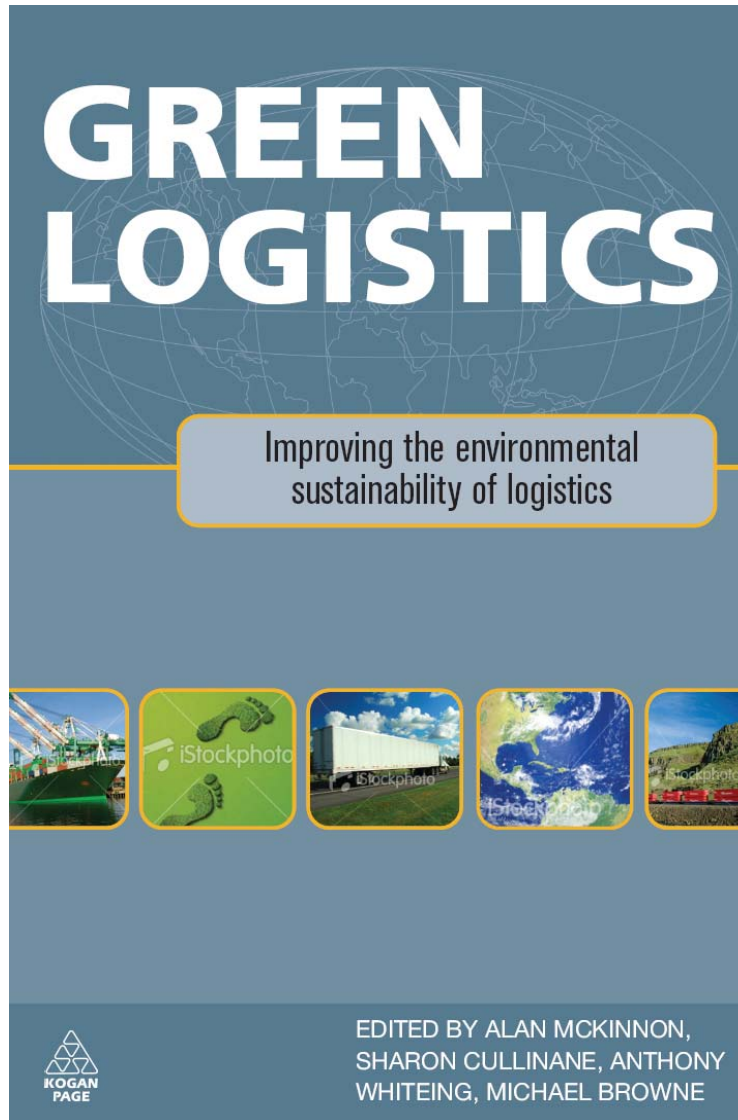
- www.greenlogistics.org
- Information on all work modules
- Latest working papers

Example – Height restrictions

- EU is considering a max height limit of 4m for trailers.
- Report: “Britain without Double-deck Lorries”
- Prof Alan McKinnon, Logistics Research Centre, Heriot-Watt University, Edinburgh
- “In terms of its impact on CO₂ emissions, this would be equivalent to adding 151,000 new cars to Britain’s roads.”



New book



Published in
March 2010

Vehicle routing & scheduling

Can planning vehicle routes and schedules make a contribution?



Inaccurate travel times

- *“Whatever speeds we set (in the software setup) the route times are always wrong, either the drivers cannot meet the planned times so we pay overtime or they are home early on job and finish. We just cannot seem to get the times right”*
- Logistics Director, Soft Drinks Manufacturer

Journey time calculations

Problems:

- *“...our (routing and scheduling) system cannot be relied upon to provide accurate results so significant manual adjustments need to be undertaken before we finalise our routes for the next day”*
 - Time windows are missed
 - Legal driving constraints stretched
 - Using resources inefficiently

The problem



Traffic Jam

Rationale for a Road Timetable

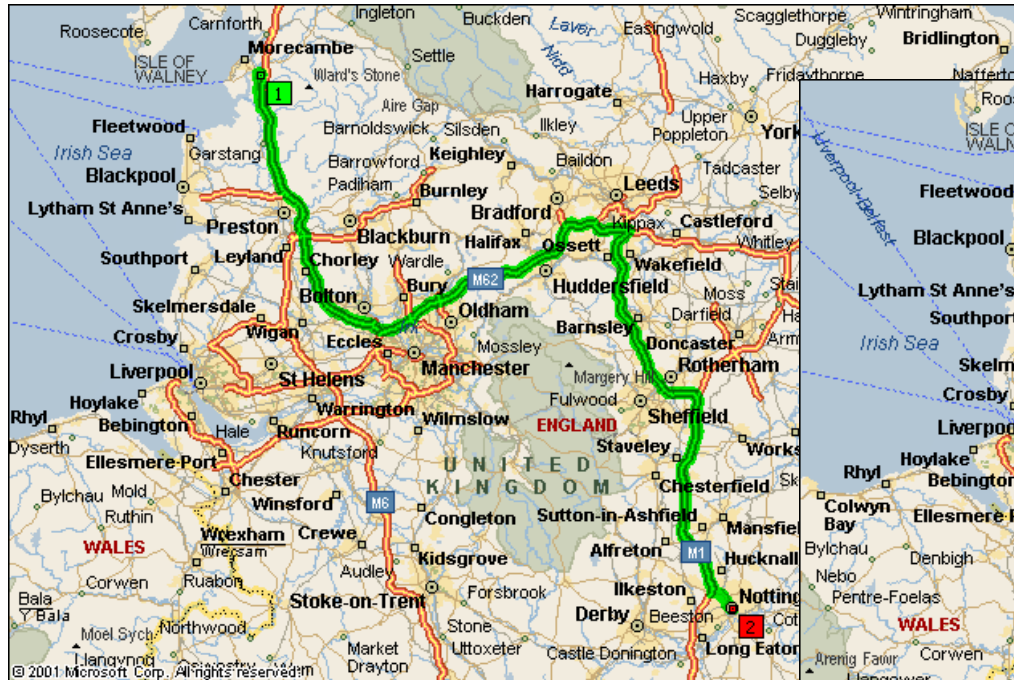
- On one section of motorway in the North of England the same commercial vehicle speeds varied in one week from 5 mph (at 08.45 on the Monday) to 55 mph (when traffic flowed freely).
- When the recorded speeds were compared over a ten week period the variation in speed recorded for the same time of day and day of the week was less than 5%.

Data sources

- Traffic information
- UK provider of traffic information
<http://www.itisholdings.com>
- Largest commercial application of FVDTM
 - Real road speeds time matched and day matched



Time dependent routes



Lancaster to Nottingham
153miles 2h 21 m



Lancaster to Nottingham
142miles 2h 42 m

The LANTIME scheduler (1)

- Given a set of customers and associated demands, central depot, vehicle fleet
- Objective: Min total time
- Constraints:
 - Vehicle capacity (weight and space)
 - Delivery time windows
 - Driving time for each route

The LANTIME scheduler (2)

- Using time-dependent data requires significant changes to the vehicle routing algorithms
- Maden W., Eglese R. and Black D. (2010) *Vehicle routing and scheduling with time-varying data: A case study*. Journal of the Operational Research Society, Vol. 61(3), pp 515-522.

Case Study

- Electrical Wholesale Distribution in the South West of England from Avonmouth
- Up to 8 vehicles - 3.5 tonne GVW box vans. No restrictions on any roads.
- Weight/Cube - No restrictions
- Time Windows - none
- Time constraint – one 10-hour shift per day including legal breaks
- 40 to 67 customers per day

SOUTH WEST PROPOSED DELIVERY AREAS



Sample solution for one day

Vehicle	1	2	3	4	5	6	7	Total time
A	538	571	573	598	152	501	0	2933

A – using uncongested speeds

Sample solution for one day

Vehicle	1	2	3	4	5	6	7	Total time
A	538	571	573	598	152	501	0	2933
B	605	628	637	716	168	587	0	3341

A – using uncongested speeds

B – using routes from A with actual speeds

Sample solution for one day

Vehicle	1	2	3	4	5	6	7	8	Total time
A	556	568	589	595	580	599	564	588	4639
B	542	577	548	551	539	551	533	532	4373

A – using uncongested speeds, reduced by 20% everywhere

B – using routes from A with actual speeds

Sample solution for one day

Vehicle	1	2	3	4	5	6	7	8	Total time
A	556	568	589	595	580	599	564	588	4639
B	542	577	548	551	539	551	533	532	4373
C	596	198	597	566	501	595	578		3632

A – using uncongested speeds, reduced by 20% everywhere

B – using routes from A with actual speeds

C – using LANTIME with actual speeds

Vehicle Routes for that day



- Uncongested routes
- LANTIME routes

Summary Statistics

Run	Total dist. (km)	Total time (min)	Total CO2 (kg)
P-20%	21796	28232	4694
C	20236	26431	4363

In this case, a reduction in CO₂ emissions of about 7%

Conclusions from case studies

- Routing and scheduling taking traffic information into account can lead to worthwhile reductions in carbon emissions
- Scope and size of reductions is dependent on factors such as
 - Whether computerised VRP systems have been used before
 - vehicle capacity and time window constraints

Other objectives

- Shortest time
- Minimum emissions
- Minimum cost

Using fuel more efficiently

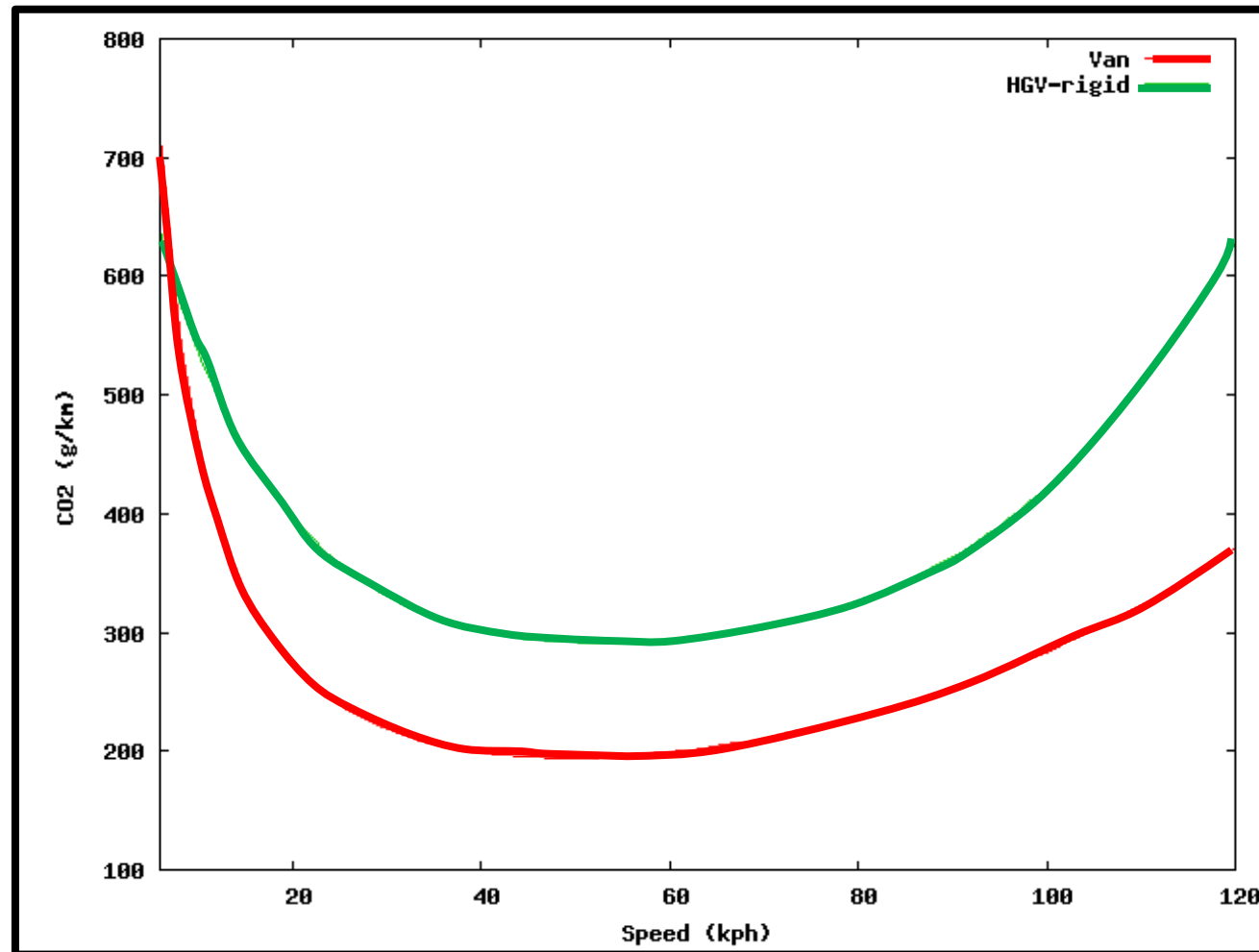
- Those elements that influence fuel consumption are:
 - Travel related factors such as speed and acceleration rates
 - Road conditions such as congestion, inclines, bends, roundabouts and traffic lights
 - Vehicle characteristics such as engine size, fuel type, payload and age

For example...



The size, weight and shape of the load will affect the fuel consumption.

CO2 Emissions

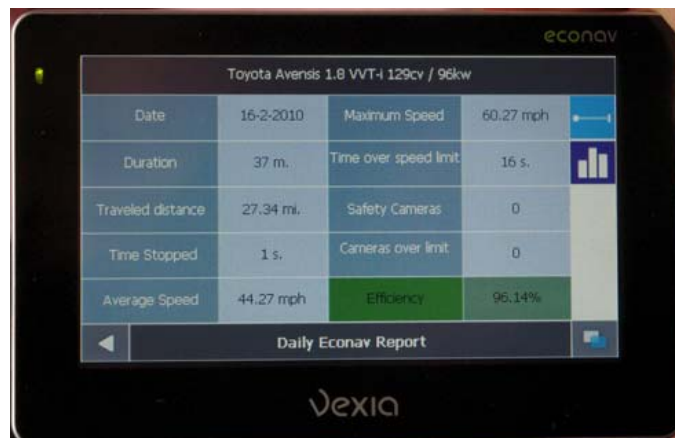


Current Work

- Modifying for least polluting rather than least time
- Modifying to take account of congestion charging

Minimising pollution or fuel

- Fuel use and hence carbon footprint depends on speed.
- Treat speed as a decision variable in the network.
- Model using approximate dynamic programming and a column generation style heuristic.
- Implement using in-cab navigation systems



Congestion charge

- General case is technically challenging
- Heuristics are being developed
- Future work to look at the design of a congestion charge scheme



Future developments

- Taking account of variation – stochastic models
- Taking account of current situation – dynamic models

Concluding remarks

- New technologies provide new tools and sources of data
- New objectives provide new problems that are technically challenging
- What should be the priorities?

Questions ?

