Vehicle Routing and the Green Agenda

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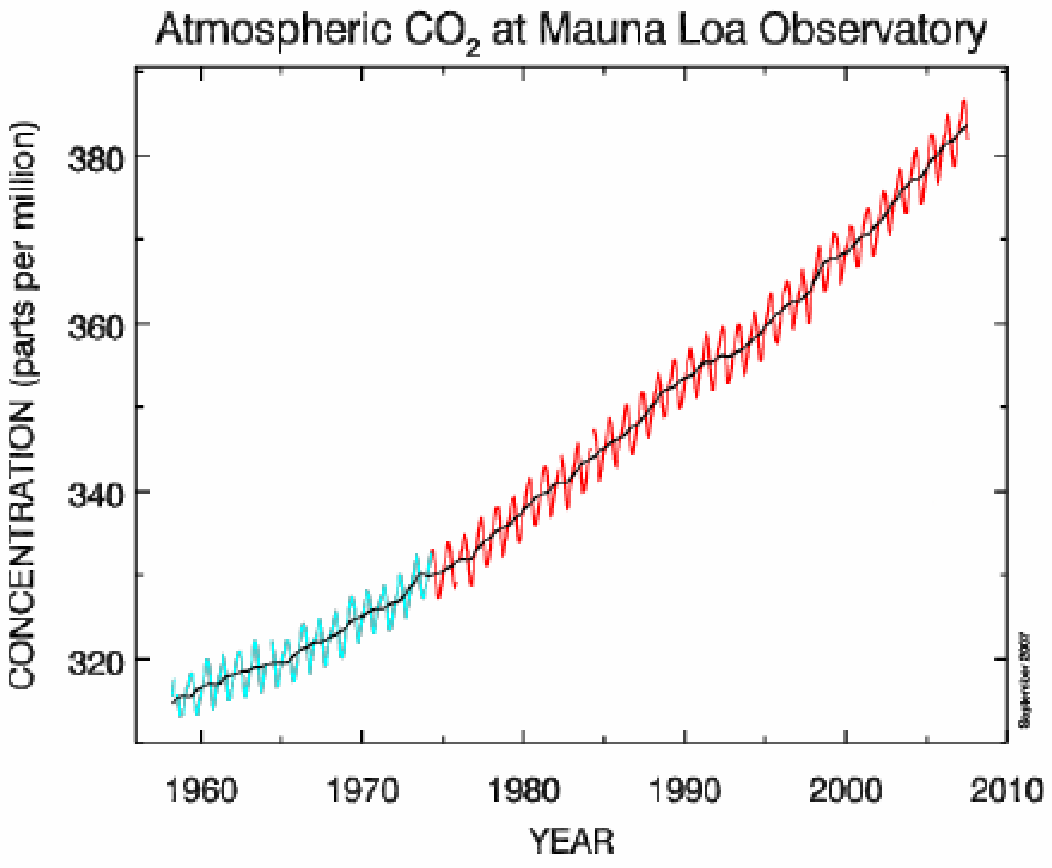
Change in atmospheric CO_2



Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii
Source: National Oceanic and Atmospheric Administration, accessed on 2nd October 2007 at:

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

How bad is it going to get?

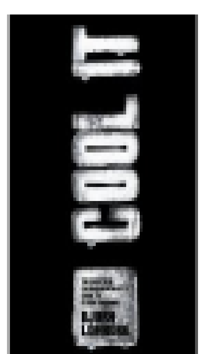
Gradual warming: sea level rise, increasing drought, declining agricultural yields, land becoming uninhabitable, more severe storm damage, loss of biodiversity / extinction of species

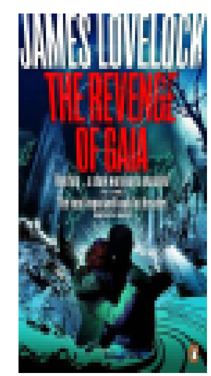
Crossing ecological tipping points:

- Warming of tropical rain forest: *switch from CO_2 sink to source*
- Melting of Arctic / Antarctic / Greenland ice-sheets: *sea-level rises by several metres*
- Thawing of the Siberian tundra – *release of methane*

climate change denial → apocalyptic vision

We are not to blame / it has happened before / it will be self-correcting / it is a political - economic - scientific conspiracy..	There is a problem but we should concentrate on other priorities	Huge problem requiring urgent response. The necessary change is manageable within existing economic and political frameworks	Mankind's greatest challenge. There is still time, but it will require draconian changes to our way of life	It's too late. Try to preserve our civilisation in an era of runaway climate change



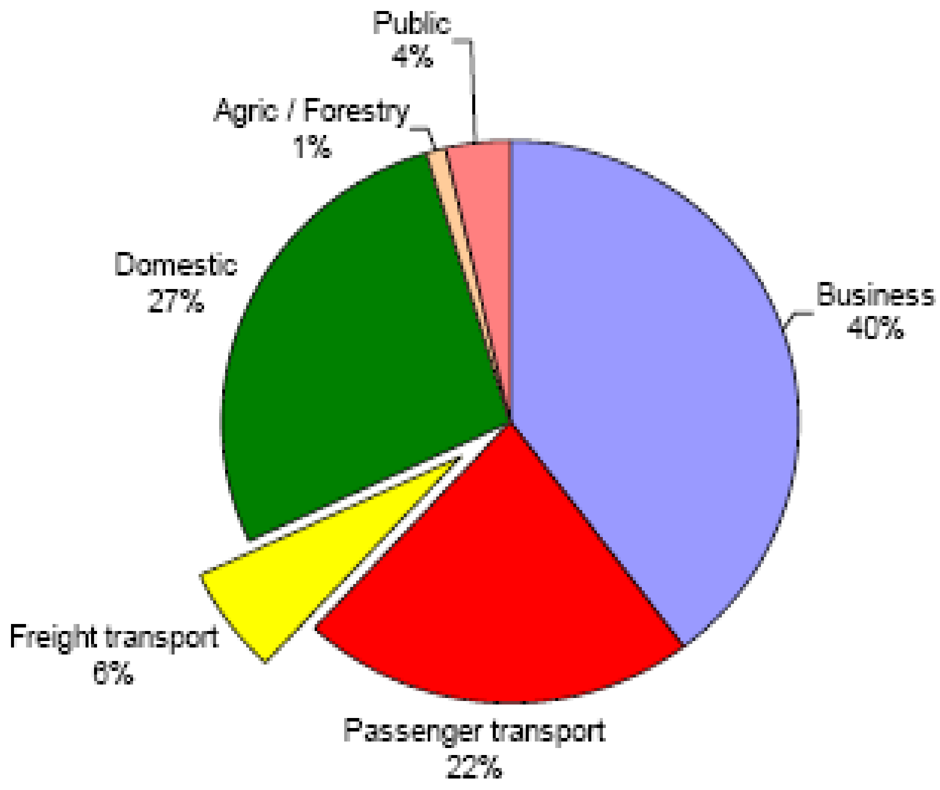


Source: McKinnon, 2008

Green Agenda Issues

- To keep the increase in global temperature by 2100 within 1- 2°C it is estimated that CO_2 must be restricted to 450 ppm.
- Governments are introducing carbon reduction targets and policies.
- Companies are concerned about their carbon footprints.
- "Green-Gold" is the ideal.

Sources of CO_2 emissions by end user: UK 2004



Based on DEFRA 2006

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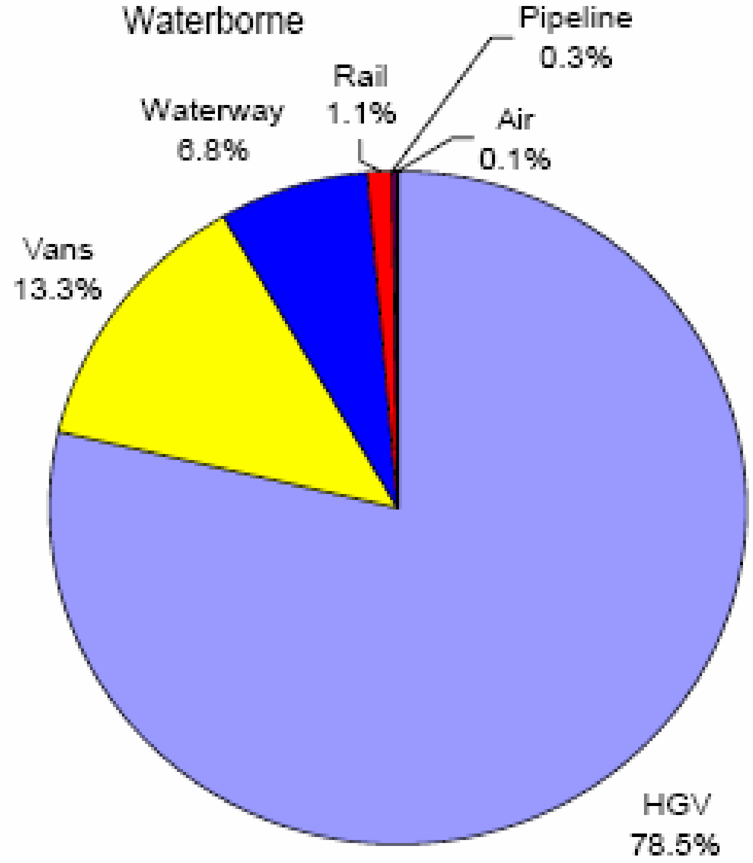
CO_2 emissions from freight transport: UK 2004

32.4 million tonnes of CO2

5.8% of total UK emissions

20.5% of transport CO2 emissions

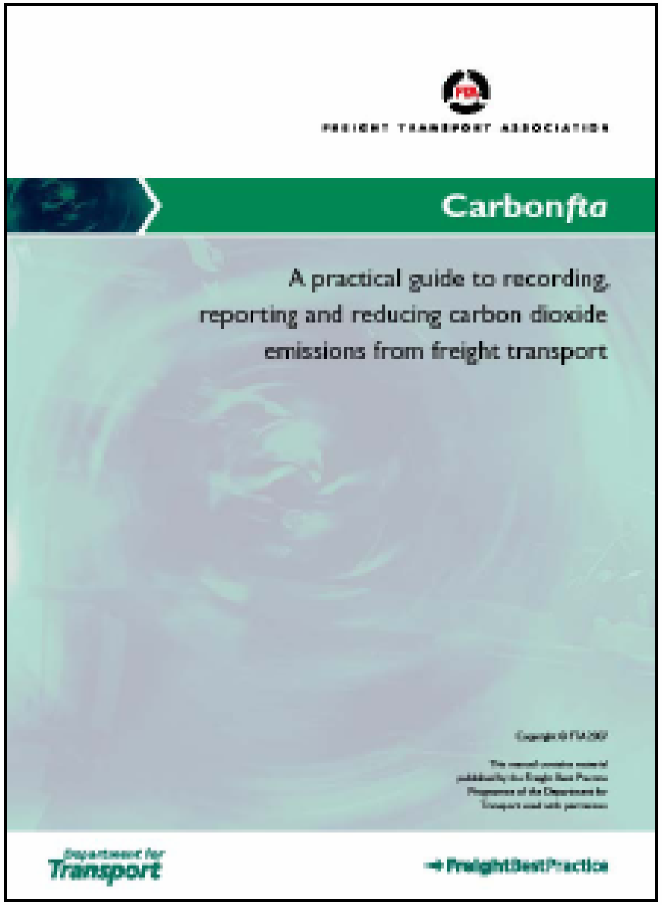


Freight Transport Industry

Companies are being encouraged to improve freight transport performance in terms of emissions as well as economic costs

For example, see Freight Best Practice guides

Even using this as marketing ploy, e.g. Lenor TV advert



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

Research Partners

- University of Leeds, *Institute for Transport Studies*
- Cardiff University, *Logistics & Operations Management supported by Computer Science*
- Heriot-Watt University, *Logistics Research Centre*
- Lancaster University, *Management Science*
- University of Southampton, *Transportation Research Group*
- University of Westminster, *Transport Studies Group*

Key Objectives

- To integrate previously uncoordinated initiatives and techniques
- To establish baseline trends against which the success of Green Logistics initiatives can be monitored
- To identify and prioritise Green Logistics measures in terms of potential environmental and economic impact
- To review the range of methodologies currently used and enhance the toolkit available for Green Logistics research
- To engage with industry and policy makers in joint Green Logistics initiatives
- To develop new analytical approaches of practical benefit to managers and policy makers

Website

- www.greenlogistics.org
- Information on all work modules
- Latest working papers
- Searchable set of references

Other research on VRP & Green issues

- Andrew Palmer (2008) The Development of an Integrated Routing and Carbon Dioxide Emissions Model for Goods Vehicles, PhD thesis, Cranfield.
- Tom van Woensel (2007) Vehicle routing with dynamic travel times: A queueing approach, EJOR.

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Current Journey Time Calculations

- Journeys between two locations
- Many methods of varying complications
  - Straight line calculations
  - Using a road network
  - Using different speeds on different roads
- Based on static times throughout the day
- Some methods will add a congestion factor onto these static times.

Current 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
  - Routing into congestion increases pollution

The problem

Data Source

A leading provider of traffic information and vehicle security services
http://www.itisholdings.com

- Largest commercial application of FVD ™
  - Real road speeds time matched and day matched
  - 96 (15 minute) time bins

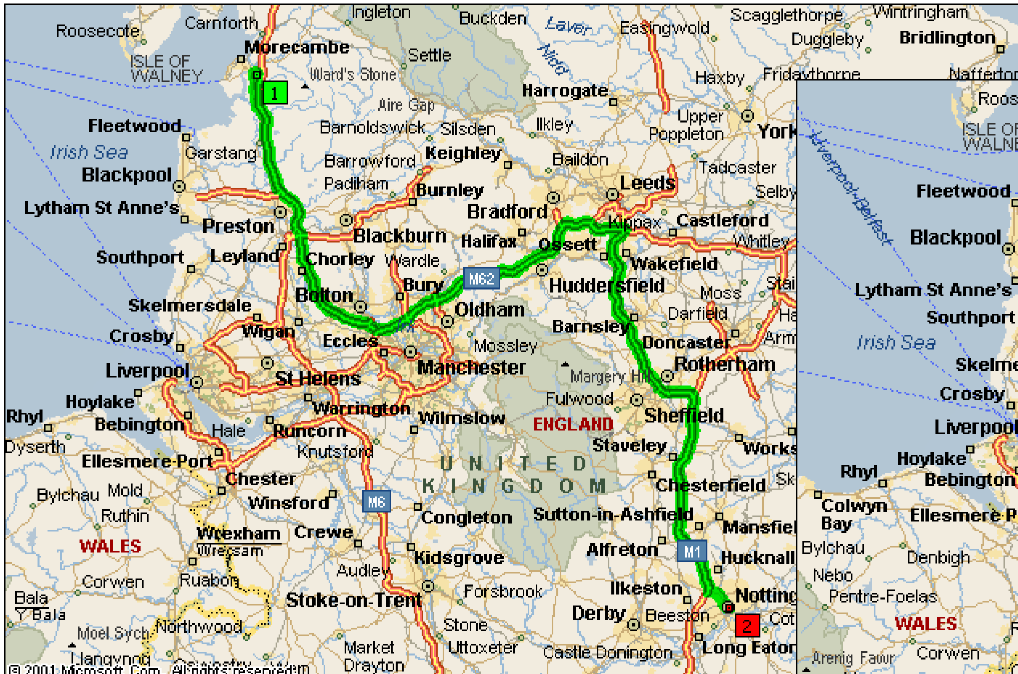
Rationale for a Road Timetable

- 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 (at 20.15 on the Wednesday).
- 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%.

Road Timetable Description

- Using FVD data we can calculate routes between two locations.
  - Firstly we need to create a digital network based on real road junctions and connecting roads.
  - Using a shortest path algorithm to find the quickest route
  - FVD travelling times are dependent on starting times
- Times calculated this way are more accurate than any of the methods discussed earlier.

Time dependent routes



Lancaster to Nottingham
153miles 2h 21 m

Lancaster to Nottingham
142miles 2h 42 m

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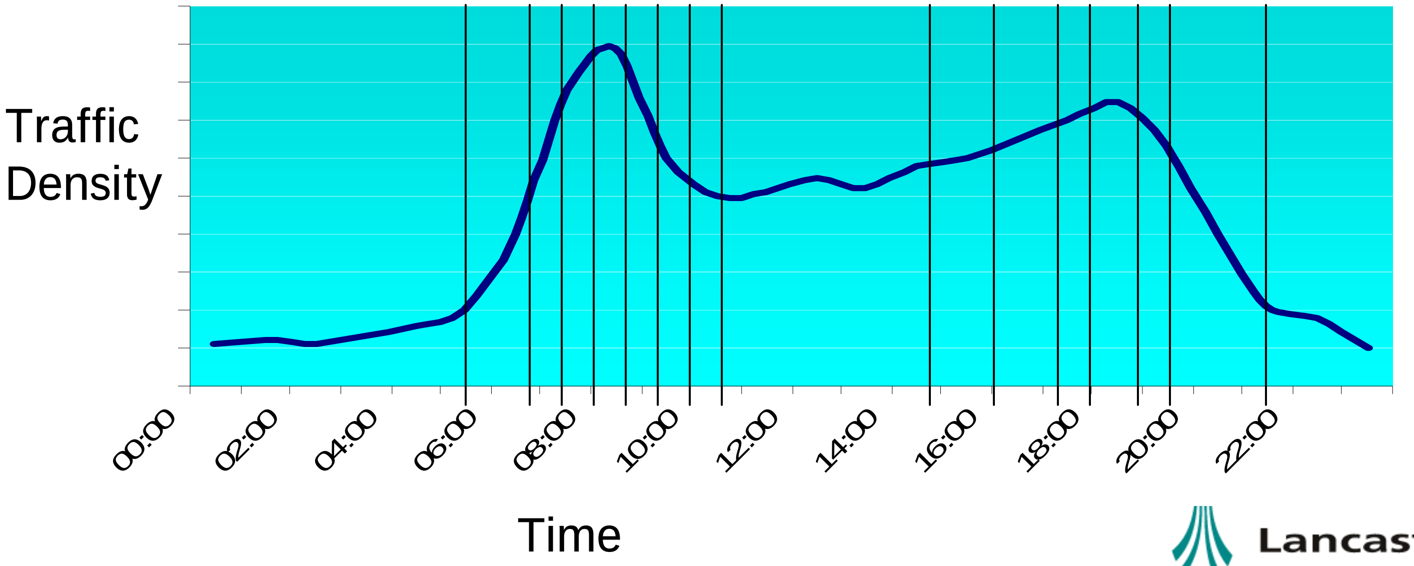
Time bins for different speeds

- The 96 time bins can in practice be reduced to about 15 different periods of time with different speeds
  - These 15 represent distinct changes in the day and are narrower around the two peak times and the build up to them



The LANTIME scheduler

- 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
- Using time-dependent data requires significant changes to the vehicle routing algorithms

Tabu search algorithm

- Uses best solution in selected neighbourhood
- Standard tabu list, aspiration criterion
- Long term memory based on penalising customers who have often been included in moves
- Accepts time-infeasible solutions, but penalises them to attain full feasibility in final solution

Dealing with time-varying travel times

- For static travel times, a neighbourhood move can be evaluated efficiently (in terms of change to the objective and feasibility).
- For time-varying travel times, either a long exact calculation is needed or an approximation (based on static times).
- If an approximation is used, then the best ones can be checked exactly before accepting the best.

Case Study

- Electrical Wholesale Distribution in the South West of England
- Type of vehicle - all 3.5 tonne GVW box vans. No restrictions on any roads.
- Weight/Cube - No restrictions
- Time Windows - none
- Time constraint – one shift per day

SOUTH WEST PROPOSED DELIVERY AREAS

ITIS Data information

- Data based on information aggregated into 15-minute time bins for a 3-month period covering February to April 2007.
- An average speed per time bin is used to construct the relevant Road Timetables.

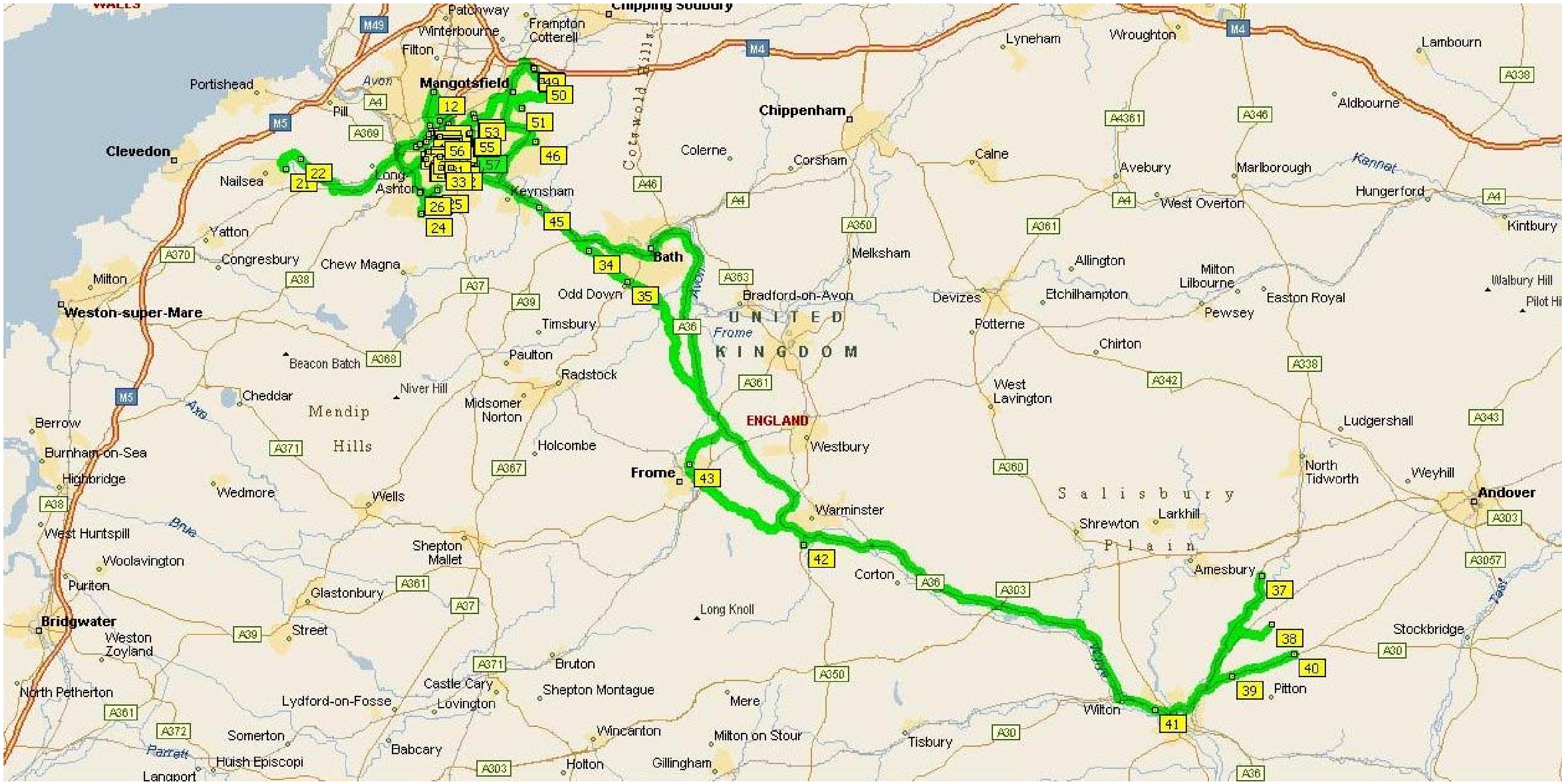
Sample Comparisons

- For eight-hour shifts including legal breaks for drive time and work time.
- Bristol – 55 locations, 2 vehicle routes
- Plymouth – 57 locations, 2 vehicle routes

Solution using uncongested times

Bristol	Time (min)	Distance (km)
Vehicle [1]	248	66
Vehicle [2]	438	259
Total	685	324

Bristol Uncongested routes



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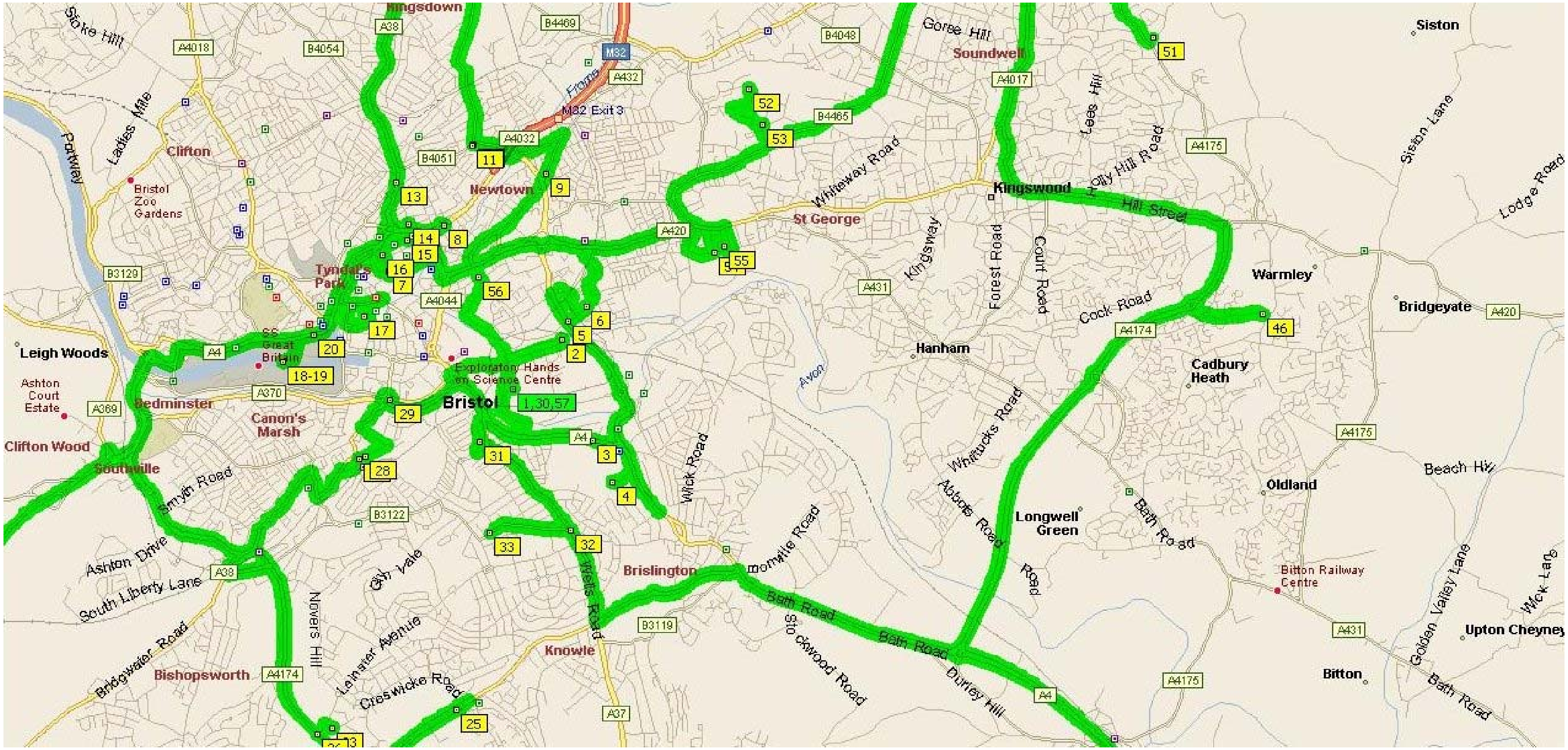
Bristol Uncongested routes detail



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Solution using uncongested routes with congested times

Bristol	Uncongested time (min)	Distance (km)	Congested time (min)
Vehicle [1]	248	66	281
Vehicle [2]	438	259	508*
Total	685	325	789

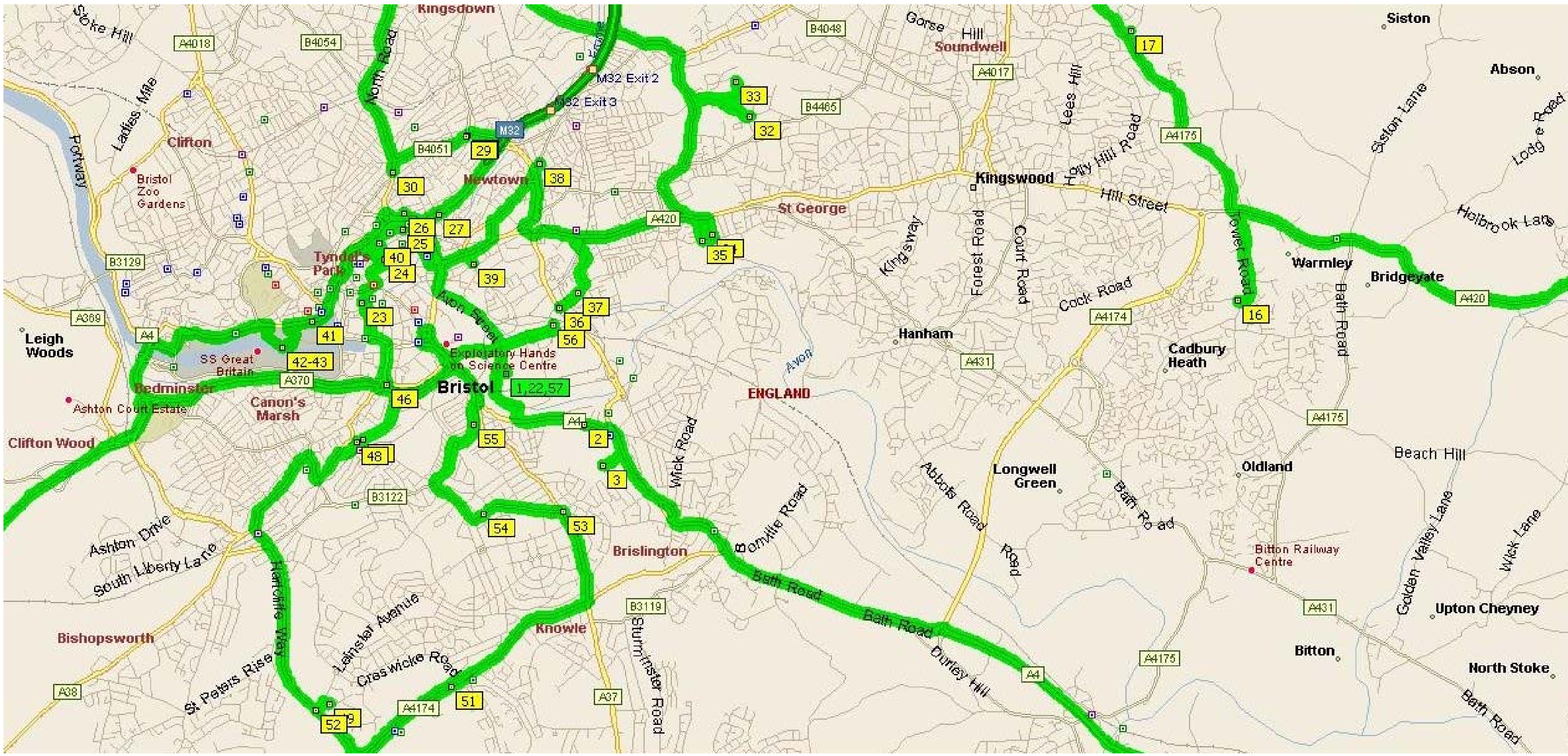
* Over max time by 28 min

Solution using Road Timetable and LANTIME

Bristol	Time (min)	Distance (km)
Vehicle [1]	460	251
Vehicle [2]	326	80
Total	785	331

No route too long and total time taken is shorter (even though total distance is 6km longer)

Bristol LANTIME solution detail



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Solution using uncongested times

Plymouth	Time (min)	Distance (km)
Vehicle [1]	448	214
Vehicle [2]	328	182
Total	775	396

Solution using uncongested routes with congested times

Plymouth	Uncongested time (min)	Distance (km)	Congested time (min)
Vehicle [1]	448	214	489*
Vehicle [2]	328	182	359
Total	775	396	848

* Over max time by 9 min

Solution using Road Timetable and LANTIME

Plymouth	Time (min)	Distance (km)
Vehicle [1]	435	195
Vehicle [2]	444	199
Total	879	394

No route too long

Future Work

- Further testing of LANTIME for other cases
- Modifying for least polluting rather than least time
- Measuring how much difference this can make in practice
- Modelling the effect of road charging schemes

Challenges

- To provide practical tools to contribute to a sustainable distribution strategy.
- To deal with the dynamic real-time situations.
- To integrate with traffic control.