Green Logistics and Vehicle Routing

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Change in atmospheric CO$_2$

Monthly mean atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii
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 CO$_2$ must be restricted to 450 ppm.
- Governments are introducing carbon reduction targets and policies.
Website

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

GREEN LOGISTICS

Improving the environmental sustainability of logistics

Published in March 2010
Vehicle routing & scheduling

Can planning vehicle routes and schedules make a contribution?
The problem
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
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

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>538</td>
<td>571</td>
<td>573</td>
<td>598</td>
<td>152</td>
<td>501</td>
<td>0</td>
<td>2933</td>
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</tbody>
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A – using uncongested speeds
Sample solution for one day

<table>
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<td>605</td>
<td>628</td>
<td>637</td>
<td>716</td>
<td>168</td>
<td>587</td>
<td>0</td>
<td>3341</td>
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A – using uncongested speeds

B – using routes from A with actual speeds
Sample solution for one day

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<td>580</td>
<td>599</td>
<td>564</td>
<td>588</td>
</tr>
<tr>
<td>B</td>
<td>542</td>
<td>577</td>
<td>548</td>
<td>551</td>
<td>539</td>
<td>551</td>
<td>533</td>
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A – using uncongested speeds, reduced by 20% everywhere
B – using routes from A with actual speeds
Sample solution for one day

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<td>551</td>
<td>533</td>
<td>532</td>
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<tr>
<td>C</td>
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<td>198</td>
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<td>595</td>
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<td></td>
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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

<table>
<thead>
<tr>
<th>Run</th>
<th>Total dist. (km)</th>
<th>Total time (min)</th>
<th>Total CO2 (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-20%</td>
<td>21796</td>
<td>28232</td>
<td>4694</td>
</tr>
<tr>
<td>C</td>
<td>20236</td>
<td>26431</td>
<td>4363</td>
</tr>
</tbody>
</table>

In this case, a reduction in CO$_2$ 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

![Graph showing CO2 emissions vs speed](image)
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
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 ?