Vehicle Routing & Scheduling: Developments & Applications in Urban Distribution

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IIT Bombay 10th April 2014
Outline

Vehicle Routing and Scheduling
Collaborative Freight Systems
B2C
Performance Based Standards
Ongoing Research
References
Vehicle Routing & Scheduling

Vehicle Routing Problem with Time Windows (VRPTW)

• Decision variables
  – schedules (trucks to customers)
  – routes (customer visiting order)

• Objective function: min. operating costs
  – Travel costs (time & distance)
  – Penalties (time windows)

• Constraints
  – Vehicle capacities
  – Customer time windows
Time windows and penalties

Penalty Cost ($) vs. Arrival Time

- $\alpha_i$ and $\beta_i$ represent the penalty costs.
- $e_i$ and $l_i$ denote the earliest and latest arrival times respectively.
Metaheuristics

- Simulated Annealing (SA)
- *Tabu Search (TS)*
- Genetic Algorithms (GA)

...have been successfully applied to VRPTW...
• An intelligent problem solving technique based on flexible memory
• Neighbourhoods examined for new solutions some moves are tabu or forbidden
• Need to:
  – Define search history
  – Determine how to generate neighbourhood solutions
• A neighbourhood
  – set of solutions formed from current solution using a simple operation

• Tabu list
  – set of moves that are not allowed to avoid repetition
General Procedure

(i) determine initial solution, this become the current solution

(ii) if stopping criteria is not satisfied, generate neighbourhood solutions from the current solution, else finish

(iii) current solution is selected from non-tabu neighbourhood solutions found in (ii), goto (ii)
Neighbourhood Generation Techniques

• **Adjacency Exchange**
  – Adjacent links for a tour are exchanged

• **Insert Exchange**
  – Tour links are randomly exchanged (2 usually)

• **Cross Exchange**
  – Segments of tours (multiple customers) are exchanged
Move Operation
Exchange Operation
• Tabu Restrictions
  – Ban moves previously made
  – Can be conditional upon improvement gained (aspiration criteria)

• Selection Criteria
  – Usually best neighbourhood solution is selected (even if no improvement gained)
Random Swap Tabu Search Example (Retail Customers)

<table>
<thead>
<tr>
<th>Current Solution</th>
<th>Route</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 5 9 1 8 12 11 3 6 4 10 7 2 0</td>
<td>430.46</td>
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<td>(5,11)</td>
<td>0 11 9 1 8 12 5 3 6 4 10 7 2 0</td>
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<tr>
<td>(2, 5) *</td>
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<td>432.43</td>
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</table>
Benefits of considering travel time variability in vehicle routing with time windows

Risk of delays modelled using stochastic programming & robust optimisation

Formed the basis for City Logistics modelling and intelligent transport systems research programs

2 International Patients registered…
Collaborative Distribution

- Shared storage location(s)
- Networks restructured using advanced vehicle routing & scheduling systems
- Distribution to outlets by areas & priority
- Substantial savings in transport costs (20-30%)
- Significant reduction in environmental & social costs
Distribute 500kg between each site

Vehicle capacity = 2000kg

Each site ≥ 1 vehicle

Transhipment possible at each site

Based on distributing electrical goods between retail shops in Melbourne

Concept could be applied to multiple carriers, horizontal collaboration (Fischer et al, 1995)
5 vehicles no transhipment
4 vehicles pickups at store w/o vehicle
4 vehicles with transhipment at stores
4 vehicles with transhipment at common location
Independent Networks from suppliers
Collaborative Network

Around 20% saving in distance travelled
Single Urban DC

- DC
- low density
- medium density
- stores
Regional DC’s
<table>
<thead>
<tr>
<th></th>
<th>Internet</th>
<th>Sales</th>
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<tr>
<td></td>
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<td>5%</td>
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<tr>
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<td>Increase (%)</td>
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<td>6.4</td>
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<tr>
<td></td>
<td>Internet Sales</td>
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<td>Deliveries to homes from RDC’s</td>
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<td>Distribution to RDC’s from MDC</td>
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<td>Total</td>
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<tr>
<td>Change (%)</td>
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</table>
E-commerce supermarket home delivery network
Extended length, 36 Mail Cages  Rigid
Standard 12.5m, 3AR 23T vs High Productivity
4AR 14.85m 28T PBS Vehicle +37% productivity
Depot Transfer Operation

Depot 1 (LF=95%)
Depot 2 (LF=90%)
Depot 3 (LF=90%)
Depot 4 (LF=87%)
Multi Drop Operation

Depot → Customer 1 → Customer 2 → Customer 3 → Customer 4

Customer N
Domestic Postal Fleet Impacts

- Estimated Kilometre reduction 29%
- Average Load Productivity increase 37%
- Cost reduction -8% Rigid truck numbers -20% (over 7 years) in Urban areas
- Generated high interest and has attracted a government and Industry scholarships
Ongoing Research

- Exact solution procedures
- Pickup & Delivery with transfers
- Intermodal networks (road & rail)
- Flexible trailer combinations
- Combining VRS with simulation (agent based modelling)
- Incorporating travel time information (dynamic routes)


