Probabilistic Arc Routing Problem

by

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Outline

• Motivation

• Arc Routing Problem with Probability

• Proposed Solution Methods

• Computational Results

• Conclusion
• The rectangle represents a Service Territory serviced by four drivers.

• They are encouraged to follow a Master Route which defines a sequence of street segments.
Benefits of Using Master Route

- Maintain the **consistency** of the routes
  - Each service provider serves roughly the same geographical area each day
  - Provide service at approximately the same time each day

- Improve the **efficiency** of delivery
  - Load packages into package cars in accordance with the pre-determined sequence
Problem Description: DARP

- The deterministic arc routing problem (DARP)
  - Given a service territory consisting of street segments
  - Construct the master route that traverses all the streets with the minimum length
  - On a particular day skip customers that do not require services
Street Segment Presence Probability

- Street segment presence probability

  - the probability that a street segment requires at least one stop during a given time period

  - high variability is observed from real-world industrial data

- Failure to address the variability due to street segment presence probability may cause inefficiency
• 7 street segments
• **B** has a small presence probability
Master Route (MR) 1 and 2 have the same length
On a particular day, B does not require a service.

Apparently, Route 1 is better than Route 2.
Street Segment Presence Probability

Red: [0, 0.2]  
Blue: (0.2, 0.6]  
Orange: (0.6, 1]
DARP Master Route
Probabilistic Master Route
Streets that need to be visited on a particular day
The Route Generated From DARP Master Route
The Route Generated From Probabilistic Master Route
Study ARP in a Probabilistic Context

- Two approaches that take into account the uncertainty in street segment presence
  - The probabilistic arc routing problem (PARP)
  - The multi-period arc routing problem (MARP)
Problem Description: PARP

- The probabilistic arc routing problem (PARP)
  - Given a service territory consisting of street segments

- Construct a master route that traverses all the street segments with the minimum expected length
Problem Description: MARP

- The Multi-period arc routing problem (MARP)
  - Given
    - a service territory consisting of street segments
    - a set of time periods (days)
    - a set of street segments that need to be serviced on each day
  - Construct a master route that traverses all the street segments with the minimum average length over all of the days
Solution Approach

- The procedure for DARP is provided by the small-package delivery company.

- We propose:
  - A Probabilistic Local Search Procedure for PARP
  - A Multi-Period Evaluation Procedure for MARP

- Both procedures utilize local search routines:
  - 1-Shift and 2-OPT
Original Master Route
1-Shift
2-OPT
Probabilistic Local Search Procedure

- Use the DARP master route as Initial Solution

- Apply 1-Shift and 2-OPT

- Use the *expected* length to evaluate each local search movement
Multi-period Evaluation Procedure

- Use the DARP master route as the initial solution

- Apply 1-Shift and 2-OPT

- Use the *average* length over all of the days to evaluate each local search movement
Computational Experiments

- Compare the performances of the master route from DARP, PARP, and MARP over
  - deterministic length
  - expected length
  - average length

- Test problems include industrial data and computer generated data (not reported here due to the length of the presentation)

- We use VC++ 6.0 and a PC with Pentium IV 2 GHz and 1.24G RAM
<table>
<thead>
<tr>
<th>Index</th>
<th># of Street Segments</th>
<th># of days</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>235</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>228</td>
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<tr>
<td>3</td>
<td>226</td>
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<td>4</td>
<td>169</td>
<td>30</td>
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<tr>
<td>5</td>
<td>147</td>
<td>30</td>
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## Running Time Comparison I

<table>
<thead>
<tr>
<th>Index</th>
<th>PARP (sec)</th>
<th>MARP (sec)</th>
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<tbody>
<tr>
<td>1</td>
<td>13553</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>11818</td>
<td>13</td>
</tr>
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<td>3</td>
<td>11482</td>
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<td>5</td>
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<tr>
<td>5</td>
<td>1567</td>
<td>3</td>
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## Deterministic Length Comparison I

<table>
<thead>
<tr>
<th>Index</th>
<th>DARP Master Route</th>
<th>PARP Master Route</th>
<th>MARP Master Route</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.1042</td>
<td>1.1206</td>
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<tr>
<td>2</td>
<td>1</td>
<td>1.1873</td>
<td>1.2045</td>
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<tr>
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<td>1.0869</td>
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<tr>
<td>4</td>
<td>1</td>
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<tr>
<td>5</td>
<td>1</td>
<td>1.1427</td>
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# Expected Length Comparison I

<table>
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<th>DARP Master Route</th>
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<th>MARP Master Route</th>
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<tbody>
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<td>1</td>
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<td>0.9783</td>
<td>0.9841</td>
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<td>2</td>
<td>1</td>
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<td>5</td>
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## Average Length Comparison I

<table>
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<th>PARP Master Route</th>
<th>MARP Master Route</th>
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<td>1</td>
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<td>0.9795</td>
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<tr>
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<tr>
<td>5</td>
<td>1</td>
<td>0.9892</td>
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Conclusion

- Studied the arc routing models for small package local routing

- PARP and MARP address the variability due to street segment presence probability

- Propose a probabilistic local search procedure and a multi-period evaluation procedure

- Computational results demonstrate savings in mileages