Integrated Intermodal Network Design with Nonlinear Inter-Hub Movement Costs

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INTRODUCTION

- Intermodal transportation uses at least two different transportation modes to move goods that are in the same transportation unit (i.e., shipping containers) throughout their route from origin to destination (Macharis and Bontekoning 2004).
- Intermodal transportation is an alternative approach that can be used to reduce transportation costs and environmental effects as compared to road transportation.
- One of the key planning decisions associated with intermodal transportation is designing its logistics network.

DIFFERENT ROUTES FOR SENDING A LOAD FROM MINNEAPOLIS TO NEW ORLEANS

INTERMODAL NETWORK DESIGN

Strategic, tactical, and operational decisions are involved in designing a logistics network. These decisions are dependent on each other and should be handled together in order to maximize the intermodal transportation system performance.

INTEGRATED INTERMODAL NETWORK DESIGN (ILND) PROBLEM

- Designs network topology
- Decisions of different time horizons are integrated in one model
- This model helps the “network operator”

MODELING

- Nonlinear inter-hub movement costs
  - Transportation cost per load depends on the amount of loads transported
  - Loads are allowed to visit as many hubs as needed to reduce the network total cost

MATHEMATICAL FORMULATION

\[ \text{Minimize} \quad F_i Y_i \quad + \quad C_{ijr} \quad t_{dp} Z_{ijr} \quad (1) \]

Subject to:

\[ X_{lp} \quad - \quad t_{lp} \quad = \quad -1 \quad \quad \forall p, \forall i \quad (2) \]

\[ X_{ij} \quad d_{pj} \quad \leq \quad M \quad Y_{ijr} \quad \quad \forall p, \forall i \in N - \{ \text{Origin} p \} \quad (3) \]

\[ Y_{ij} \quad = \quad H \quad (4) \]

SOLUTION APPROACH

- A heuristic approach that combines a Genetic Algorithm (GA) and the Shortest Path Algorithm (SPA) was developed

COMPUTATIONAL RESULTS

- Randomly generated instances and the Civil Aeronautics Board (CAB) dataset were used
- Heuristic results for random 10-node instances compared to optimal solutions

<table>
<thead>
<tr>
<th># of Loads</th>
<th># of Modes = 2</th>
<th># of Modes = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4,933.9</td>
<td>3,991.6</td>
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<tr>
<td>2</td>
<td>4,972.4</td>
<td>3,930.4</td>
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<tr>
<td>3</td>
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<td>3,994.4</td>
</tr>
<tr>
<td>4</td>
<td>5,037.9</td>
<td>4,034.6</td>
</tr>
<tr>
<td>5</td>
<td>5,075.5</td>
<td>4,075.4</td>
</tr>
</tbody>
</table>

Heuristic results for total cost and # of hubs for random 25 and 50-node instances

<table>
<thead>
<tr>
<th>Instance</th>
<th>Measure</th>
<th>N = 25</th>
<th>N = 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cost</td>
<td>110,275</td>
<td>120,175</td>
</tr>
<tr>
<td>2</td>
<td># of Hubs</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Cost</td>
<td>120,275</td>
<td>125,175</td>
</tr>
<tr>
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</tr>
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CONCLUSIONS

- Heuristic method provides optimal solutions for small instances and keeps large proportion of optimal hubs as instance sizes grow
- Large fixed hub installation costs affect number of open hubs
- Additional transportation modes reduce the total transportation cost, however problem size increases and the solution approach requires more time to find solutions (especially for 50-node networks)

FUTURE RESEARCH

- Improving the load route and transportation mode selection portion of the heuristic
- Integrating other related elements that influence the intermodal logistics network design problem such as transportation time and congestion at terminals

REFERENCES

- Oregon State University 2004

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