Real World Practical Influences on Vehicle Routing and Urban Delivery

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Overview

- Introduction – Supply Chain
- Global Supply Chain Trends
- Routing in Real World Delivery Networks
  - Algorithm Stability
- Urban Delivery
- Future Research Directions
What is a Supply Chain?

Upstream Suppliers  \hspace{1cm} The Integrated Firm  \hspace{1cm} Downstream Customers

plan, make, deliver

Product flow  \hspace{1cm} Information flow  \hspace{1cm} Financial flow

Customer Relationship Management  Customer Service Management
Demand Management  Order Fulfillment
Manufacturing Flow Management  Procurement
Product Development  Returns Management
Trends in Supply Chain Mgt.

*Macro-Trends* from recent book:

Population Growth & Urbanization
Factors related to Transportation Congestion

- Increased global import/export volumes
- Limited port capacity and equipment
- Aging transportation Infrastructure
- Increased delivery to urban/city customers
- Labor disputes and strikes
- Increased size of container ships

Real world congestion can impact routing decisions made by shippers and carriers
Ant colony optimization for vehicle routing problem
  ◦Bell & McMullen (2004), Advanced Engineering Informatics

Logistics Oriented VRPs
  ◦Bell & Griffis (2010), Journal of Business Logistics

Triangle Inequality Violations in the VRP
  ◦Fleming et al. (2013), European Journal of Operational Research
Vehicle Routing Problem Example
Christofides, Mingoazzi, & Toth (‘79) provide a set of 14 VRP test problems in the literature:
- First ten of these problems were symmetric, uniformly distributed and randomly generated on a Euclidean plane.
- Last four problems had clustering to help represent real world routing challenges.

Other test problems sets typically generate “uniformly” distributed demand locations to test new routing algorithms:
- May not represent the spatial demand patterns or challenges of actual delivery in today’s supply chains.
Algorithm Stability

- Christofides, Mingozzi, Toth (1979) observe that algorithm performance varies for different problems in their set
  - Some algorithms performed better on “realistic problems” with clustering
  - Some were “stable” across spatial patterns
- Similar results observed by:
  - Ballou (1990) proposes logistics VRP problem set
  - Bell & Griffis (2010) applied ACO to Ballou set
  - Erdogan & Miller-Hooks (2012) who study Green Vehicle Routing
Many VRP test sets in the literature have randomly and uniformly distributed demand locations.

- Creates a normally distributed distance matrix (Schilling et al. 2000, EJOR)

The distance matrices of real world supply chain VRPs are impacted by both the spatial orientation of demand locations and the transportation structure or connectivity between the locations.
Research Question

“How will varying spatial dispersion of demand locations and transportation network structures, as captured in the distance matrices of real world routing problems, impact VRP solution quality and the stability of different heuristic algorithms?”
Ant Colony Optimization & Logistics Oriented VRPs – JBL ‘10

- Ballou presented a set of 20 stop in 1990 that were logistics oriented...motivated by real world demand patterns faced by transportation carriers:
  - Urban – Rural
  - Coastal
  - Sector
  - Random
  - Cluster

- Applied ACO to these test problems for first time
- Found issues of algorithm stability and called for additional research on larger problems generated from empirical “real world” company data
An initial experiment was conducted using data from a major US retailer that operates over 5000+ locations across the US

- Problem #1 – distribution from Southern California DC to 118 locations
- Problem #2 – distribution from Minnesota DC to 115 locations

Two metaheuristic algorithms were tested with fixed search parameters across problems

- Ant Colony Optimization
- Simulated Annealing
Testing conducted for each experimental cell:

- Each meta-heuristic algorithm run 30 times
- Uses a route length restriction based on driver time
- Solutions generated using C++ program

<table>
<thead>
<tr>
<th></th>
<th>Sim Annealing</th>
<th>ACO</th>
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</thead>
<tbody>
<tr>
<td><strong>South California</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best (miles)</td>
<td>960.68</td>
<td>1012.61</td>
</tr>
<tr>
<td>Average</td>
<td>1032.52</td>
<td>1023.88</td>
</tr>
<tr>
<td>stdev</td>
<td>44.26</td>
<td>8.28</td>
</tr>
<tr>
<td><strong>Minnesota</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best (miles)</td>
<td>6144.22</td>
<td>6008.08</td>
</tr>
<tr>
<td>Average</td>
<td>6345.55</td>
<td>6273.81</td>
</tr>
<tr>
<td>stdev</td>
<td>76.24</td>
<td>152.46</td>
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</table>
Future Research on Logistics Oriented Routing

- Distinguish more distribution types from empirical routing data from all Distribution Centers
- Conduct more robust testing, to include more runs, multiple days from different DCs and sensitivity to heuristic tuning
- Testing of additional algorithms
Future Research on Logistics Oriented Routing

- Final results should provide evidence about which heuristic algorithms to use for certain distance matrices and actual real world logistics conditions
  - Implications for software providers
  - Implications for algorithm testing
  - In line with Cordeau et al. (2000) criteria for evaluating a VRP heuristic

- Can be extended to intra-city studies on congestion and urban routing
Urbanization

- Population Changes
- Traffic Issues
- Demand Concentration
- Delivering in the “home stretch”
How do businesses overcome the transportation challenges of operating in urbanizing areas?
Urban Stakeholder Framework

Under 2nd Review at Journal of Business Logistics
Research Question: What urban area characteristics affect the transportation system and delivery within the urban area?

In-depth literature review

Multiple disciplines
  ◦ Sociology
  ◦ Geography
  ◦ Civil engineering
  ◦ Business
# Urban Area Typology

<table>
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<tbody>
<tr>
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<td>Network Central</td>
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<tr>
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<td>Network Peripheral</td>
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<tr>
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<td>Air</td>
<td>Sprawled</td>
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<tr>
<td></td>
<td>Water</td>
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</table>

1st Dissertation Manuscript, targeted for Transportation Journal
Industry Profile

Exchange Industry (Las Vegas, NV)

Heavy Industry (Pittsburgh, PA)

Cognitive Cultural (Silicon Valley, CA)
Modal Diversity

Diverse Modal Access (New Orleans, LA)

Limited Modal Access (Albuquerque)
Clustering Profile

Single Cluster (Chicago)

Multiple Clusters (Los Angeles)

Sprawled (Atlanta)
Network Centrality
Network Central (Dallas–Fort Worth, TX)
Network Centrality
Network Peripheral
Billings, MT
Network Centrality
Exploratory Case Study

Research Question

◦ Which transportation strategies are best suited to assist companies in various urban areas in achieving their joint goal of a demand-satisfied population?
# Finding Strategies that Match the Typology – Exploratory Case Study

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2nd Dissertation Manuscript, targeted for Decision Sciences
Simulation Study

- Research Question
  - How well do the different strategies perform in different urban environments and is there an optimal combination of strategies and urban factors?
Simulation Study

- AnyLogic Agent-Based Simulation
  - System behaviors
  - Response to a disturbance

- Bottom-up system description
  - Emergent patterns
  - Agent/Environment Interaction
## Simulation Study

<table>
<thead>
<tr>
<th>Environmental Characteristics (From Paper 1)</th>
<th>Logistics Strategies (From Paper 2)</th>
<th>Performance Criteria (Melnyk et al., 2010)</th>
</tr>
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<tbody>
<tr>
<td>Clustering Profile</td>
<td>Lot Size</td>
<td>Cost</td>
</tr>
<tr>
<td>Network Central</td>
<td>Number of Deliveries</td>
<td>Responsiveness</td>
</tr>
<tr>
<td></td>
<td>Warehouse Size</td>
<td>Security</td>
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<td>Sustainability</td>
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<td></td>
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<td>Resiliency</td>
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<td></td>
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<td>Innovation</td>
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## Simulation Study

<table>
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<th>Demand Agents</th>
<th>Modal/Network Agents</th>
<th>Inactive Agents</th>
<th>Strategic Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer</td>
<td>Airport</td>
<td>Route Centers</td>
<td>Vehicles</td>
</tr>
<tr>
<td>Retailer</td>
<td>Seaport</td>
<td>Cluster Centers</td>
<td>Distribution Centers</td>
</tr>
<tr>
<td>Customer</td>
<td>Railroad Terminal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Motor Exits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Agent Based Simulation
Agent Based Simulation

Customers Supplied: 1
Orders Outstanding: 141
Driver Utilization:
  Maximum: 0
  Minimum: 0
  Average: 0
Agent Based Simulation
Simulation Study

- Model Verification
- Model Validation
- Experimentation
- Data Analysis
Future Urban Research

- Additional typology dimensions
- International Focus -- China
- Focus on logistics interaction with additional social and environmental systems
- Incorporating characteristics into vehicle routing models
- Inter-city vs. Intra-city logistics
Real World Changes are forcing companies to face new conditions and constraints

- Spatial variation in global supply and demand locations
- Growing urbanization and transportation congestion

Relevant and Rigorous Research on transportation and product delivery

- Logistics Oriented VRP algorithms
- Urban Delivery Strategies for unique Urban areas
Advice to Younger Scholars

- Be strategic about building “streams” of research
  - Use good scientific methods that may initially include qualitative and empirical research to understand a phenomenon
  - Build rigorous engineering solutions that real world transportation practitioners will value
- Select co-authors with complimentary skills and similar work patterns
Questions?

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