Creating Efficiencies in Last Mile Delivery through Workforce Management

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Joint work with Karen Smilowitz, Northwestern University and Mike Hewitt, Loyola University
What opportunities are there beyond reducing cost?

- Researchers are exploring customer service issues and how they relate to transportation cost
  - Time to rethink the models that we are using

- Introduce workforce management and its advantages
- Discuss new research looking to expand the customer service objectives
- Extend the planning horizon to achieve more efficiency
- Discuss general trends in workforce management
Workforce management

**Key idea:** Performance improves as drivers perform the same tasks multiple times (consistency)

**Customer Familiarity**
Reduce the cost per visit to a customer as the frequency of visits to that customer increases

*If the customer set varies significantly by day, it may be advantageous to consider a more aggregate level*

**Region Familiarity**
Reduce the cost per visit to a region as the frequency of visits to that region increases
Does workforce management matter and what does it cost?

“Many UPS drivers work the same route for 20 or 25 years. … UPS drivers form a real bond with customers... A formal program that gathers sales leads from drivers generates volume of more than 60 million packages a year, largely because drivers take tremendous ownership of their customers and routes.

In contrast, a major competitor reserves the right to reconfigure some drivers' routes with five days' notice, meaning their customers, service area and earnings power can change quickly.”

- UPS Corp. (2006)

“While desirable to route the same drivers to the same customers each and every day, that level of consistency can be inefficient. As Hugh Gigante of Appian notes, ‘If we tell a customer that it costs them $100 a day to keep the same drivers servicing the same customers, most fleets will decide it isn't worth the cost.’”

- Partyka and Hall (2010)
Trade-off between customer familiarity and travel distance

Introducing workforce metrics into routing decisions with a small weight has a high reward with a low cost.
Home health care delivery perspective

• Great benefit to patients and significant reduction in costs
• Considerable inefficiencies due to lack of funding and shortage of trained personnel
• Competing objectives make the problem interesting
  – Transportation cost/miles driven
  – Consistency: patient visited by same care provider at (roughly) same time of day - impacts quality of care
  – Work-load balancing: impacts care provider job satisfaction and retention
• There is no one home health care routing problem - different agencies are interested in optimizing different objectives
Continuity of care goals for schedules and routes

- A patient should be seen by the same nurse as often as possible
- A patient should always be seen at roughly the same time of day
  - Agencies quote patients a time window for each visit
  - We’ll assume a fixed set of time windows we can assign to a patient (8 am - 9 am, 9 am - 10 am, etc.)
  - Our goal will be to always have a patient visited during the same time window

- **Consistency of time windows should increase both patient satisfaction and driver performance**
Instance from NY care provider

- 1414 patients spread over 45 zip codes
- Divided into five regions
- Days that service requested known a priori
  - From 1 to 5 days of service requested per week
- Several distributions tested

<table>
<thead>
<tr>
<th>Percentage of customers</th>
<th>Number of Days Service Requested</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>
Achieving time consistency more difficult

Increase in consistency above minimum with 5% degradation in travel costs

<table>
<thead>
<tr>
<th>Customer distribution</th>
<th>Driver</th>
<th>Time Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0-50-50-0</td>
<td>0.1%</td>
<td>0.4%</td>
</tr>
<tr>
<td>0-0-35-55-10</td>
<td>0.4%</td>
<td>4.3%</td>
</tr>
<tr>
<td>0-0-40-40-20</td>
<td>0.5%</td>
<td>4.4%</td>
</tr>
<tr>
<td>0-0-45-45-10</td>
<td>1.2%</td>
<td>3.6%</td>
</tr>
<tr>
<td>10-10-15-25-40</td>
<td>0.0%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>
Length of problem horizon may be too short

• Home health care relationships last considerably longer than one week
• Most providers only plan week-by-week, or even simply daily
• What happens when planning horizon extended to two to three months?
• Stochastic model designed so that data can be easily collected and applied
  – Simple predictions on number of expected customers
• Extending planning horizon can help with staffing and reducing operational costs
Problem instances

- Urban has patients dispersed over 5 mile radius, Rural-15 miles
- Patient visit requires one hour
- 200 patients with 70% likelihood that patient requests service on a day
- Number of patients requesting service is not constant each week

<table>
<thead>
<tr>
<th>Instance</th>
<th>Begin/End</th>
<th>Geographic setting</th>
<th>Horizon</th>
</tr>
</thead>
<tbody>
<tr>
<td>35U8</td>
<td>35</td>
<td>Urban</td>
<td>8 weeks</td>
</tr>
<tr>
<td>70U8</td>
<td>70</td>
<td>Urban</td>
<td>8 weeks</td>
</tr>
<tr>
<td>35R8</td>
<td>35</td>
<td>Rural</td>
<td>8 weeks</td>
</tr>
<tr>
<td>70R8</td>
<td>70</td>
<td>Rural</td>
<td>8 weeks</td>
</tr>
<tr>
<td>55U12</td>
<td>55</td>
<td>Urban</td>
<td>12 weeks</td>
</tr>
<tr>
<td>110U12</td>
<td>110</td>
<td>Urban</td>
<td>12 weeks</td>
</tr>
<tr>
<td>55R12</td>
<td>55</td>
<td>Rural</td>
<td>12 weeks</td>
</tr>
<tr>
<td>110R12</td>
<td>110</td>
<td>Rural</td>
<td>12 weeks</td>
</tr>
</tbody>
</table>
Nurse utilization remains constant with Long Term planning

![Graph showing nurse utilization over weeks with constant percentage from 82% to 89%]

- **Weeks:** 1, 2, 3, 4, 5, 6, 7, 8
- **Nurse Utilization:** 82% to 89%
- **Lines:**
  - **WbW** (black line)
  - **LT** (red line)

The graph illustrates the constant nurse utilization from Week 1 to Week 8 with minor fluctuations.
**Number of nurses decreases**

<table>
<thead>
<tr>
<th>Instance</th>
<th>Week-by-Week</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>35U8</td>
<td>31.0</td>
<td>2.8</td>
</tr>
<tr>
<td>70U8</td>
<td>39.6</td>
<td>6.7</td>
</tr>
<tr>
<td>35R8</td>
<td>36.8</td>
<td>2.8</td>
</tr>
<tr>
<td>70R8</td>
<td>46.6</td>
<td>6.5</td>
</tr>
<tr>
<td>55U12</td>
<td>36.1</td>
<td>3.8</td>
</tr>
<tr>
<td>110U12</td>
<td>50.4</td>
<td>9.1</td>
</tr>
<tr>
<td>55R12</td>
<td>41.1</td>
<td>4.7</td>
</tr>
<tr>
<td>110R12</td>
<td>54.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Average</td>
<td>42.1</td>
<td>5.7</td>
</tr>
</tbody>
</table>
## Travel time reduction over week-by-week model

<table>
<thead>
<tr>
<th>Instance</th>
<th>Travel Time (Hours)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week-by-Week</td>
<td>Long Term</td>
</tr>
<tr>
<td>35U8</td>
<td>669</td>
<td>611</td>
</tr>
<tr>
<td>70U8</td>
<td>848</td>
<td>800</td>
</tr>
<tr>
<td>35R8</td>
<td>1367</td>
<td>1190</td>
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<tr>
<td>70R8</td>
<td>1881</td>
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<td>55U12</td>
<td>1115</td>
<td>1051</td>
</tr>
<tr>
<td>110U12</td>
<td>1693</td>
<td>1577</td>
</tr>
<tr>
<td>55R12</td>
<td>2384</td>
<td>2166</td>
</tr>
<tr>
<td>110R12</td>
<td>2955</td>
<td>2695</td>
</tr>
<tr>
<td>Average</td>
<td>1614</td>
<td>1461</td>
</tr>
</tbody>
</table>
Matching models with industry

Model options:
- Minimize Travel Distance (TD)
- Encourage consistency through Objective (OBJ)
- Enforce consistency through Constraints (CON)

Importance of driver familiarity

- High
- Medium
- Low

Daily variation in customer set

Assume 5-day period

No variation: All frequency of 5
Some variation: Mixed frequencies
Complete variation: All frequency of 1
Matching models with industry

**Importance of driver familiarity**

- **High**
  - VRP (repeat daily)
  - CON
  - CON

- **Medium**
  - OBJ
  - OBJ

- **Low**
  - OBJ with small workforce weight
  - OBJ with small workforce weight or TD/VRP for each day

**Daily variation in customer set**

- **No variation:** All frequency of 5
- **Some variation:** Mixed frequencies
- **Complete variation:** All frequency of 1
Matching models with industry: practitioner findings

Daily variation in customer set

- **Peapod grocery home delivery**
- **Benefits of driver familiarity**: Efficiency; customer comfort; tips; doorman access
- **Customer characteristics**: Mix of consistent orders/changing time windows
- **Challenges of driver consistency**: Time windows and work shifts
- **Innovative ideas**: Dynamically adjust time window openings

**Importance of driver familiarity**

- **High**
- **Medium**
- **Low**

**Daily variation**

- **No variation**: All frequency of 5
- **Some variation**: Mixed frequencies
- **Complete variation**: All frequency of 1

**CON**

- OBJ with small workforce weight
- OBJ with small workforce weight or TD/VRP for each day
Matching models with industry: practitioner findings

Daily variation in customer set

<table>
<thead>
<tr>
<th>Importance of driver familiarity</th>
<th>No variation: All frequency of 5</th>
<th>Some variation: Mixed frequencies</th>
<th>Complete variation: All frequency of 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>UPS residential delivery</td>
<td>OBJ with small workforce weight</td>
<td>OBJ with small workforce weight or TD/VRP for each day</td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td>OBJ</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
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Benefits of driver familiarity: Efficiency; doorman access; revenue generation

Customer characteristics: Low volume; 1 stop per segment daily

Challenges of driver consistency:

Variation in demands; balance loads

Innovative ideas: Core area of 3/4 drivers; subdivide into trace

High

Low

Medium

VRP (repeat daily)
Matching software with models

What are companies doing to shift within the grid?

Work around software - Peapod

Change software - UPS

Importance of driver familiarity

<table>
<thead>
<tr>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>No variation:</td>
<td>Some variation: Mixed frequencies</td>
<td>Complete variation: All frequency of 1</td>
</tr>
<tr>
<td>All frequency of 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model:
- VRP (repeat daily)
- PVRP
- PVRP (if region matters)
- VRP (repeat daily)

Objective:
- Min travel cost
- Min travel cost + workforce cost
- Min travel cost + workforce cost
- Min travel cost

Daily variation in customer set
Questions?