Emerging problems and challenges in routing

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ESSEC Business School in Paris

SPOC, Paris, November 21-22, 2019
Outline

- E-commerce
  - Recent trends
  - Customer requirements
- Last-mile delivery
  - Issues
  - New strategies / technologies
- Emerging challenges in routing
  - Release and due dates
  - Routing and crowdshipping
  - Time windows management
  - Dynamic pricing
Explosion of e-commerce

E-commerce boom and preference for convenience drive demand for new delivery options and features.

Online retail volume in Western Europe:

- Share of total retail
  - 2012: 106
  - 2016: 162
  - 2020: 238 (11% p.a.)

Domestic B2C shipments in Western Europe:

- Shipments per adult
  - 2012: 12.0
  - 2016: 14.3
  - 2020: 17.0 (4% p.a.)

Relative importance of features:

- Percent of constant sum
- Which delivery features matter most to you?
  - Price of delivery: 20
  - Speed of delivery (e.g., same-day): 20
  - Alternative delivery destination (e.g., parcel locker): 15
  - Flexibility of delivery time (e.g., scheduled): 11
  - Other: 10

1 Included countries are Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Norway, Sweden, Switzerland, UK.
2 Only delivery features included, not general delivery conditions (e.g., goods not broken).

McKinsey & Company | Source: Forrester; Datamonitor; online survey conducted in June 2013, n = 1,016 (UK, France, Germany, and Sweden)
Same-day delivery

Why is same-day delivery exploding?

- Black et.al (2015) “the majority of the people buy in-store because they have the ability to touch and feel the products and to gain the instant gratification of walking out with the purchase”
- Same-day delivery allows to receive the goods bought after a few hours from the placement of an order
- Side (2017) “Millennials are not spending as much time looking for a deal as they are looking for instant gratification”
Same-day delivery

The New York Times

Last-Minute Shoppers Increasingly Trust Only Amazon to Deliver
Those types of arrangements are increasingly important to retailers, analysts say, because they give the retailers greater control over customers’ deliveries. *One late Christmas delivery can be enough to ward off shoppers,* says Sriram Sridhar, chief executive of LateShipment.com, who advises retailers to preemptively inform customers if it looks like their items will be delayed.
Last-mile delivery

The final leg in a B2C delivery service whereby the consignment is delivered to the recipient, either at the recipient’s home or at a collection point

Distribution cost in same-day delivery
IT IS NECESSARY TO REDUCE LAST-MILE COSTS IN ORDER TO DEVELOP AN EFFICIENT SAME-DAY DELIVERY POLICY
Technologies for last-mile delivery

Weights of parcels delivered by Amazon

- Less than 5 lbs: 64.5%
- Between 5 and 10 lbs: 21.5%
- Greater than 10 lbs: 14%
Technologies for last-mile delivery

Autonomous Ground Vehicles
Technologies for last-mile delivery

Droids
Technologies for last-mile delivery

Drones
Technologies for last-mile delivery

Trunk delivery

https://incardelivery.volvocars.com/
Strategies for last-mile delivery: crowdshipping

- Crowdsourcing is a concept derived from the notion that a business can outsource certain functions to the crowd (Howe, 2006).

- Crowdsourced delivery (crowdshipping) utilizes personal vehicles to deliver packages to residents and/or business.

- Crowdsourcing provides an effective way of matching demand (orders) and supply (vehicle capacity) and thus improving transportation efficiency (Bocken et al., 2014).
Crowdsourcing implies very low overhead costs to operate. The cost savings are on average of 29.7%
Routing problems and last-mile delivery

New problems emerge

- Routing with Drones
- Trunk delivery
- ....

- Routing with release dates
- Routing with crowdshipping

- Time windows assignment
- Dynamic pricing
ROUTING PROBLEMS WITH RELEASE DATES
Consolidation centers

Goods are sorted, consolidated and delivered to final customers
Background and applications

Arrival

Sorting

Distribution
Arrival and distribution times are overlapping

Contrary to what happens in classical

- VRP
- VRPTW
- IRP
- ...

NEW DECISION: SHOULD I STAY OR SHOULD I GO?
The traveling salesman problem with release dates (TSP-rd)

Archetti, Feillet, Mor, Speranza, Dynamic traveling salesman problem with stochastic release dates, EJOR 2020

- A complete directed graph $G(V,A)$
- A traveling time $t_{ij}$ associated with each arc
- A release date $r_i$ is associated with each customer $i$, with $r_i < r_j$ for $i < j$
TSP-rd

- No capacity constraint
- One vehicle
- Objective

Minimize the maximum completion time:

Traveling time +

Waiting time at the depot
Different routes with, possibly, waiting time in between
Deterministic release dates

\[ R_1 \quad R_2 \quad R_3 \quad R_4 \quad R_5 \quad R_6 \]
Is it realistic?

- Release dates represent the time at which the parcels that have to be delivered to customer arrive at the depot.
- These parcels are transported by vehicles departing from suppliers and traveling to the depot.
- These vehicles may face unexpected conditions affecting the traveling time.

**RELEASE DATES ARE NOT DETERMINISTIC!**
Stochastic release dates
Is it realistic?

- You may assume to have an estimation of the distribution of the traveling time.
- Once you know that the vehicle has departed from the supplier, you may estimate the release date.
- And what about GPS-equipped vehicles?

**STOCHASTIC AND DYNAMIC RELEASE DATES**
Stochastic and dynamic release dates
Objective function

MINIMIZING THE EXPECTED COMPLETION TIME

Recursive formula
Solution approach: reoptimization + ILS

Stochastic
Full probabilistic information

Deterministic
Conditional expected value

How?
Iterated Local Search

- Initial solution
- DR
- LS

Ending condition?

no

yes

Final solution
Computational tests

- Different widenesses of release dates and percentage of customers with dynamic and stochastic release dates
Computational tests

- Compare stochastic and deterministic model

- Evaluate a myopic policy where the vehicle starts as soon as a parcel is available at the depot
### Results: gaps from BK

<table>
<thead>
<tr>
<th></th>
<th>Avg. Deterministic</th>
<th>Avg. Stochastic</th>
<th>Avg. &quot;myopic&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta = 0$</td>
<td>2.69</td>
<td>0.72</td>
<td>11.96</td>
</tr>
<tr>
<td>$\delta = 0.5$</td>
<td>2.96</td>
<td>1.40</td>
<td>14.74</td>
</tr>
<tr>
<td>$\delta = 1$</td>
<td>3.10</td>
<td>1.34</td>
<td>10.85</td>
</tr>
<tr>
<td>$\beta = 0.5$</td>
<td>1.91</td>
<td>1.28</td>
<td>24.22</td>
</tr>
<tr>
<td>$\beta = 1$</td>
<td>3.79</td>
<td>0.90</td>
<td>11.10</td>
</tr>
<tr>
<td>$\beta = 1.5$</td>
<td>3.05</td>
<td>1.29</td>
<td>2.23</td>
</tr>
<tr>
<td>Avg.</td>
<td>2.92</td>
<td>1.16</td>
<td>12.52</td>
</tr>
</tbody>
</table>
Results: number of ILS iterations in 5 minutes

<table>
<thead>
<tr>
<th>Size</th>
<th>Deterministic</th>
<th>Stochastic</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-46</td>
<td>718</td>
<td>18</td>
</tr>
<tr>
<td>45-41</td>
<td>715</td>
<td>63</td>
</tr>
<tr>
<td>40-36</td>
<td>-</td>
<td>201</td>
</tr>
<tr>
<td>35-31</td>
<td>613</td>
<td>226</td>
</tr>
<tr>
<td>30-26</td>
<td>2248</td>
<td>500</td>
</tr>
<tr>
<td>25-21</td>
<td>1765</td>
<td>500</td>
</tr>
<tr>
<td>5-1</td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>
Interesting hints

- The stochastic models provide better results but it is much more time-demanding than deterministic
  - Probably not suitable for online setting

- The myopic approach is comparable to the other two approaches in one setting
  - No comparison in terms of computing time!
Interesting hints

The suitability of a solution approach highly depends on the practical setting
ROUTING AND CROWSHIPPING
ON-LINE Process

The customer uploads the service request.

The platform approves the request and assigns it to the first occasional driver who accepts.

The occasional driver picks up the package to the depot.

The occasional driver delivers the package to the customer.

The customer confirms the receipt of the package on the app.

The occasional driver receives the compensation.

<table>
<thead>
<tr>
<th>Time</th>
<th>Service</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00 PM - 7:30 PM</td>
<td>2 hr</td>
<td>$52 - $66</td>
</tr>
<tr>
<td>6:00 PM - 8:00 PM</td>
<td>2 hr</td>
<td>$52 - $66</td>
</tr>
<tr>
<td>6:00 PM - 8:00 PM</td>
<td>2 hr</td>
<td>$35 - $50</td>
</tr>
<tr>
<td>6:30 PM - 8:30 PM</td>
<td>2 hr</td>
<td>$36 - $50</td>
</tr>
</tbody>
</table>
The (offline) vehicle routing problem with occasional drivers (VRPOD)

Archetti, Savelsbergh, Speranza, The vehicle routing problem with occasional drivers, EJOR, 2015

- Set of customer orders
- Fleet of vehicles → Routing cost
- Set of ODs → Compensation

Two compensation schemes:

1. Based on tour length
2. Based on detour
OBJECTIVE

Minimize the sum of the cost incurred by regular drivers (routing cost) and occasional drivers (compensation)
Solution approach: matheuristic

**MATHOD**

Multi-start matheuristic

- Tabu Search for routing
- MILP for the assignment of customers to ODs
MAIN GOAL

Gain initial quantitative insights in the potential benefits of crowdshipping for last-mile delivery
Instance C201 with $|K| = 100$
Analysis of a specific instance

VRP solution
Analysis of a specific instance

Routes and destinations of ODs not used
## Results over all instances

<table>
<thead>
<tr>
<th>% cost reduction w.r.t VRP</th>
<th>% routes reduction w.r.t. VRP</th>
<th>% OD used</th>
<th>% OD cost w.r.t. total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1° comp. scheme</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.21</td>
<td>56.83</td>
<td>75.22</td>
<td>30.17</td>
</tr>
<tr>
<td><strong>2° comp. scheme</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.72</td>
<td>56.47</td>
<td>70.75</td>
<td>20.54</td>
</tr>
</tbody>
</table>
More realistic setting

Customer orders arrives online, while the delivery is taking place

HOW TO FACE THIS?
The (online) vehicle routing problem with occasional drivers (O-VRPOD)

Archetti, Guerriero, Macrina, The Online Vehicle Routing Problem with Occasional Drivers, submitted

Same setting as before with the exception that

- Each OD can serve more than one customer
- TWs are associated with both Ods and customers
- Customer order arrives online!
What can you do?

Simple insertion heuristic

vs.

Insertion + route reoptimization
Gainings of route reoptimization

<table>
<thead>
<tr>
<th># customers</th>
<th>Max gaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>4.93%</td>
</tr>
<tr>
<td>50</td>
<td>4.67%</td>
</tr>
<tr>
<td>100</td>
<td>11.82%</td>
</tr>
<tr>
<td>200</td>
<td>10.85%</td>
</tr>
</tbody>
</table>

! High benefits from route reoptimization
Remarks

- Crowdshipping might help in facing the challenges related to reduced delivery times in last-mile delivery

- Substantial cost savings

- Great business opportunity

WHAT IS THE RIGHT COMPENSATION FOR ODs?
ATTENDED HOME DELIVERIES
Still the most widely diffused delivery option
Challenges

Most people would like to be served in the same time slot (typically after work)

→ High peak of requests

→ Unbalanced workload

What to do?
Challenges

One possibility could be to offer wide time windows slots:

- Customers are required to stay at home waiting for their parcel for long
- This increases the probability of failed delivery

→ Not a good option
So...

Improve the management of short time windows slots!

- Time windows management
- Pricing
Time windows management

Possible strategies:

- Restrict the set of time window slots offered to customers
- Assign the time slot to each customer (no choice for the customer)
- Customers clustering
Pricing

What if the previous strategies does not work?

PROVIDE INCENTIVES TO CHOOSE THE RIGHT TW!

EXTREMELY FASCINATING AND CHALLENGING TOPIC
Dynamic pricing

The main idea is to link the price of delivery to customer to the opportunity cost

[6pm;8pm]
Dynamic pricing

- The literature is growing
- How to determine the opportunity cost?
- Modeling customer behavior (behavioral OR)
- Extremely challenging and completely innovative topic
CONCLUSIONS
The explosion of e-commerce gives rise to enormous challenges and provides a fertile and promising ground for excellent research.

Great opportunity for exploring fascinating new routing problems.

Ad-hoc solution techniques needed.
THANK YOU FOR YOUR ATTENTION