The Collaborative Selective Vehicle Routing Problem
Vehicle routing in a collaborative environment

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Overview

The Selective Vehicle Routing Problem

Introduction to the Collaborative Environment

Solving of the Collaborative Problem
   Strategic positioning
   Gain Sharing (or Cost Allocation)

A simulation study

Concluding Remarks
Imagine...

- A central depot
- A set of $N$ clients, waiting to be served

But...

- Only a limited number of resources (trucks) is available
- Usage of a truck is limited (distance, time)

Therefore...

- Only a limited number of clients can be served now
Imagine...
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Therefore...

- Only a limited number of clients can be served now
The Collaborative Environment introduced

Imagine...

- A central depot
- 3 partners, each having a set of clients to be served
- Each partner possesses one vehicle
The Collaborative Environment introduced

**Global Result**
- 8 clients are served (2-3-3)

**Introduce Collaboration**
- The three partners form a strategic alliance
- One vehicle can serve clients from different partners in the same trip
The Collaborative Environment introduced

Global Result
- 8 clients are served (2-3-3)

Introduce Collaboration
- The three partners form a strategic alliance
- One vehicle can serve clients from different partners in the same trip

Global Result Collaboration
- 11 clients are served (3-3-5)
A collaboration is more than calculating routes

- Companies remain independent entities
  - Results will be evaluated only on personal gains
  - Every partner wants his (important) clients to be part of the solution

Strategic positioning → Solving of the underlying VRP → Gain sharing

Feedback
How do I behave in the coalition?

“Whatever the result will be, I agree”
versus
“All my (important) clients should be part of the solution”

The partners are given the possibility to set a cost for all of their clients, that is to be paid by the group if the client is not taken into the final solution.
How do I behave in the coalition?

“Whatever the result will be, I agree”
versus
“All my (important) clients should be part of the solution”

The partners are given the possibility to set a cost for all of their clients, that is to be paid by the group if the client is not taken into the final solution

Compensation for non-delivery (CND)
How do I behave in the coalition?

- Different CND for every client
- Clients with a higher cost are more likely to be part of the solution
- Significant differences in CND will pull the solution away from maximal efficiency in favour of the expensive clients
- Number of clients visited will lower
How do I behave in the coalition?

Global Result
- 8 clients are served (2-3-3)

Global Result Collaboration
- 11 clients are served (3-3-5)

Global Result Collaboration (CND)
- 9 clients are served (3-3-3)
“Setting up a coalition should be profitable”
“How much of the coalition cost should I pay?”
“Coalition gains should be divided in a fair way”

The cost allocation method should give an incentive to the partners to behave flexible.

- CND is cost for coalition and should be kept as low as possible
Divide and Conquer

- We compare two different cost allocation approaches
  - Shapley Value
  - CND-weighted allocation
Divide and Conquer

- We compare two different cost allocation approaches
  - Shapley Value
  - CND-weighted allocation

Shapley Value

\[
x_i = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(n - |S| - 1)!}{n!} (\nu(S \cup \{i\}) - \nu(S))
\]

- Put forward by the CO³-consortium as possible best practice (standard)
- Cost allocation based on the impact of a partner on every subcoalition
- Ability to reward flexible behaviour
Divide and Conquer

- We compare two different cost allocation approaches
  - Shapley Value
  - CND-weighted allocation

### CND-weighted allocation

\[
x_i = M_i + \frac{CND_i}{\sum_i CND_i} (C(N) - \sum M_i)
\]

- Separable cost \((M_i)\) + weighted division of remaining cost
- Only based on specific colSVRP parameters (*client location & CND policy*)
A simulation study

- Own-generated Test instances
- 3-partner coalitions
- Different scenarios
  - Impact of variable CND
  - Distance from the depot
  - Client Clustering
- Partner 1 has a variable compensation for non-delivery (CND) cost, for partners 2 and 3 the CND is fixed to 100
- For every variable setting, results are averaged over 30 different instances
Impact of Compensation for non-delivery

Client locations are generated randomly

- If CND-values are the same, an equal number of clients is served.
- Raising the CND makes your clients more important, more clients will be taken into the final solution.
Impact of Compensation for non-delivery

Similar behaviour of both allocation methods

Shapley punishes inflexibility more
Clients of Partner 1 are located relatively far from the depot

- If CND-values are the same, partners with more accessible clients will be favoured.
- Unfavoured clients need to be significant expensive (high CND value) to make the longer trip valuable.
Distance from depot

- Forcing the clients of partner 1 in the solution increases the coalition cost, which is penalized in both methods.
- Due to non-monotonic increasing costs, allocations above 100% and below 0% can be found with Shapley.
Clients belonging to the same partner are clustered in one region of the solution space. On average, clients of Partner 3 are located closer to the depot.

- The cluster closest to the depot is favoured (see Scenario 2)
- If clients are located further, they need to be significant expensive to be favoured
- Favouring one partner is at the expense of the furthest, flexible partner
Client Clustering

**CND-weighted cost allocation**

- CND-weighted method is based on the final routing solution. Less clients in the solution $\rightarrow$ lower cost (Partner 2)

**Shapley Value cost allocation**

- Shapley Value is based on all sub-coalitions. Closer to the depot $\rightarrow$ higher stand-alone efficiency $\rightarrow$ lower cost (Partner 3)
To conclude

- Joining forces enables to exploit new synergies
- A collaborative problem is more than the sum of the partners
- The behaviour of partners affects both optimal route and cost allocation
- The interaction between cost allocation and routing should not be neglected
To conclude

<table>
<thead>
<tr>
<th>Shapley Value CA</th>
<th>CND-weighted CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓  An established method recognized by the industry</td>
<td>✓  Direct incentive towards flexibility for the colSVRP</td>
</tr>
<tr>
<td>✓  Efficiency of all sub-coalitions</td>
<td>✓  Easy to understand/calculate</td>
</tr>
<tr>
<td>×  Equal service in final solution may not be equally charged to the partners</td>
<td>✓  Cost is never negative or above 100% of coalition cost</td>
</tr>
<tr>
<td>×  Allocations above 100% and below 0% possible</td>
<td>×  Only based on the final solution</td>
</tr>
<tr>
<td></td>
<td>×  Parameters other than client location and CND are neglected</td>
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</tbody>
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