Determining collaborative profits in coalitions formed by two partners with varying characteristics

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Motivation
Freight transportation – room for improvement
1. Around 27% of the trucks in the road network are empty.
2. The average load factor (capacity used) is around 60%.
Horizontal collaboration
Collaborative environment

Customers company A
Customers company B
Central depot
Operational plan – Company A

- Customers company A
- Customers company B
- Central depot
Operational plan – Company B

Customers company A
Customers company B
Central depot
Operational plan – Coalition

Customers company A

Customers company B

Central depot
Collaborative aspects

• **Coalition gain**: sum of the standalone costs minus the coalition cost

• **Main incentive**: the coalition gain is always non-negative

**Issues**

• How is the coalition gain allocated to the partners?
  — Allocation method (Shapley Value, nucleolus, …)

• Different companies have different **characteristics** (business models)
  — Number of orders
  — Order sizes
  — Flexibility
Research questions

• Which characteristics have the strongest influence on the coalition gain?
• Which companies are more suitable to collaborate? (lead to the highest coalition gain)

bol.com
- Plenty of orders
- Orders of small size
- Not flexible

CATERPILLAR
- Small number of orders
- Orders of large size
- Very flexible

lavache qui rit:
- Moderate number of orders
- Orders of medium size
- Somehow flexible
Simulation study
Simulation setup

- Determine the gain of coalitions formed by two partners with different characteristics
- Coalition gain divided equally among the partners
- Long-term operational plan involving several days (PVRP)
Long term operational plan - PVRP

Operating conditions
• Same aspects as the VRP
  — Limited vehicle capacity
  — Homogeneous fleet
• Planning horizon of several days
• Each customer is available during a subset of days

Additional constraint
• Each customer should be served in a day that it is available

Two decision levels

Routing (for each day)
Assignment of customers (to days)
Long term operational plan - PVRP

Days (operational plan)

Customers A (served)

Customers A (served)

Customers A (not served)

Customers B (not served)

Central depot
Long term operational plan - PVRP

Days (operational plan)

Customers A (served)

Customers A (served)

Customers A (not served)

Customers B (not served)

Central depot
Customers A (served)

Customers A (served)

Customers A (not served)

Customers B (not served)

Central depot

Days (operational plan)
Simulation setup

- Determine the gain of coalitions formed by two partners with different characteristics
- Coalition gain divided equally among the partners
- Long-term operational plan involving several days (PVRP)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Levels</th>
<th>Partner</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of orders</td>
<td>5, 15, 25, 35</td>
<td>A</td>
<td>noA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>noB</td>
</tr>
<tr>
<td>Average order size</td>
<td>3, 6, 9, 12, 15</td>
<td>A</td>
<td>aosA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>aosB</td>
</tr>
<tr>
<td>Maximum number of days an order can be delayed</td>
<td>0, 1, 2, 3</td>
<td>A</td>
<td>mdA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>mdB</td>
</tr>
</tbody>
</table>

Extra info: Truck capacity equal to 20 and a plan horizon of 7 days
Results - General scenario
General scenario – Number of orders

Coalition gain

- $noA = 5$
- $noA = 15$
- $noA = 25$
- $noA = 35$

(noB)
General scenario – Order size

Coalition gain

aosA = 3  aosA = 6  aosA = 9  aosA = 12  aosA = 15

aosB

23
General scenario – Ability to delay orders

Coalition gain

\(mdA = 0\) \(mdA = 1\) \(mdA = 2\) \(mdA = 3\)

\(mbB\)
Results - Case study
Case study - interaction

$(nOA = 35, aosA = 3, mdA = 0)$

Coalition gain

$aosB = 3$  $aosB = 6$  $aosB = 9$  $aosB = 12$  $aosB = 15$

$pOB$
Case study - interaction

(noA = 35, aosA = 3, mdA = 0)

Coalition gain

mdb = 0
mdb = 1
mdb = 2
mdb = 3

aosB

3 6 9 12 15
Conclusions
Conclusions

• Average order size
  – Most influential characteristic
  – Best coalitions involve complementary order sizes

• Number of orders
  – The more the merrier

• Ability to delay orders (flexibility)
  – Milder influence
  – Beneficial when exploited in the joint operational plan only

• Conclusions limited to the operational conditions considered!
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