University of Antwerp
Operations Research Group
ANT/OR

The Collaborative Selective Vehicle Routing Problem

Vehicle routing in a collaborative environment

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Overview

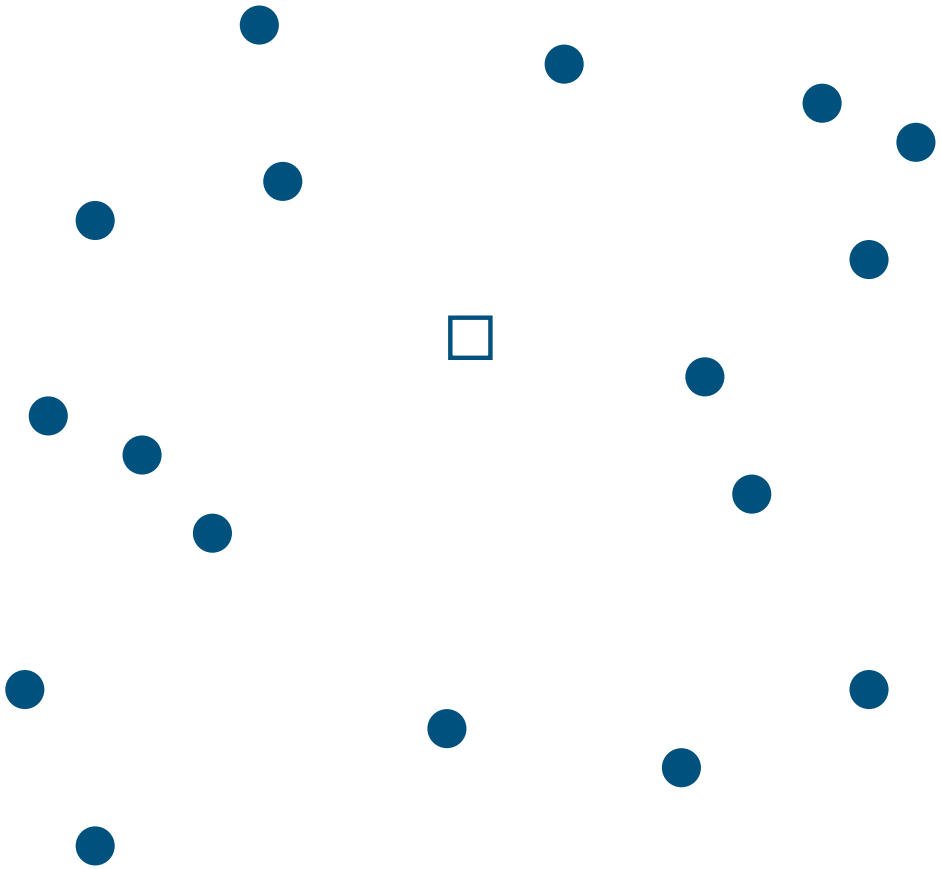
The Selective Vehicle Routing Problem

Introduction to the Collaborative Environment

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

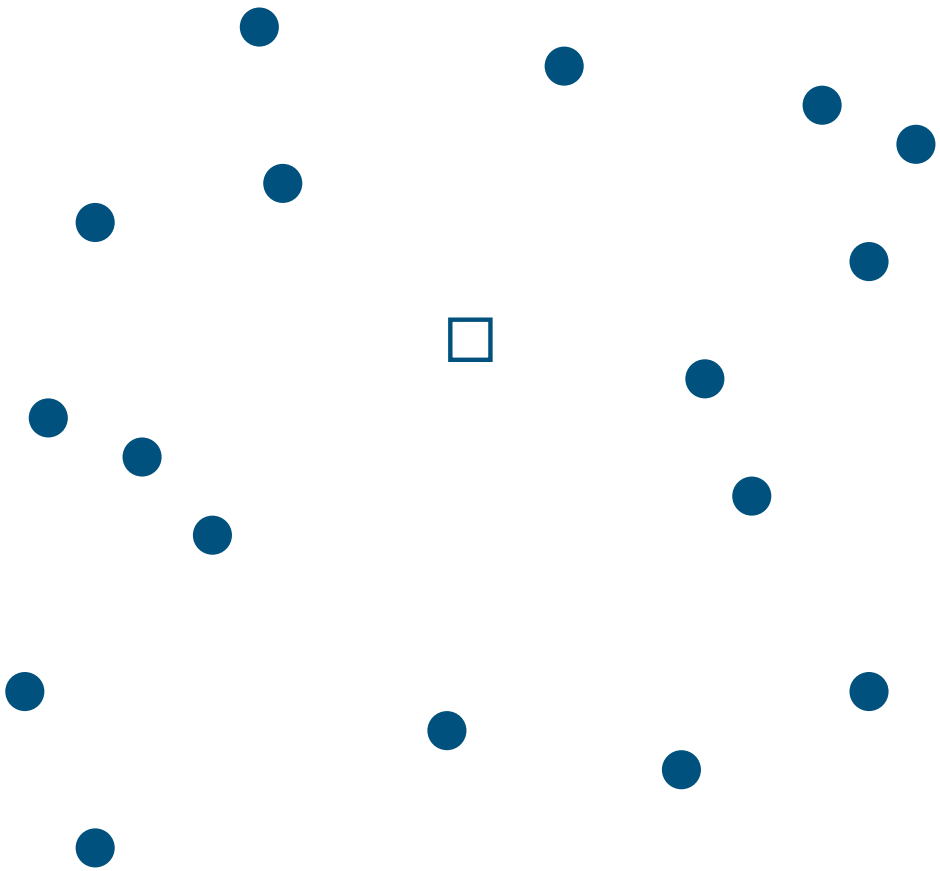
A simulation study

Concluding Remarks



Imagine...

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



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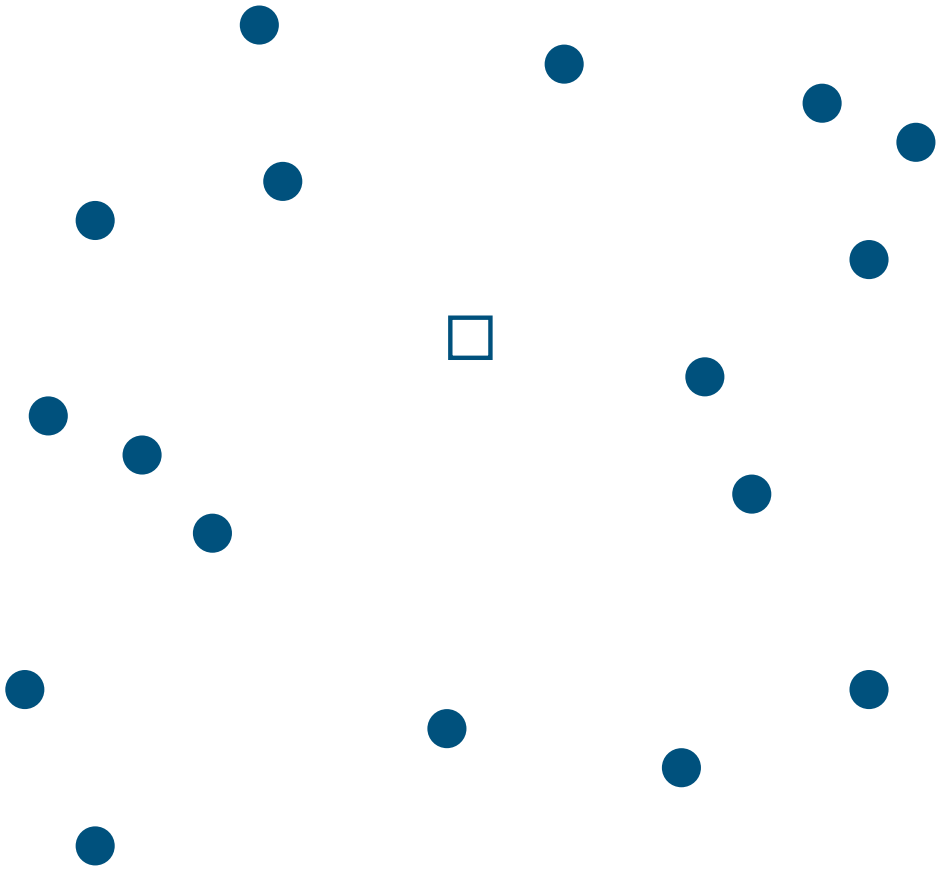

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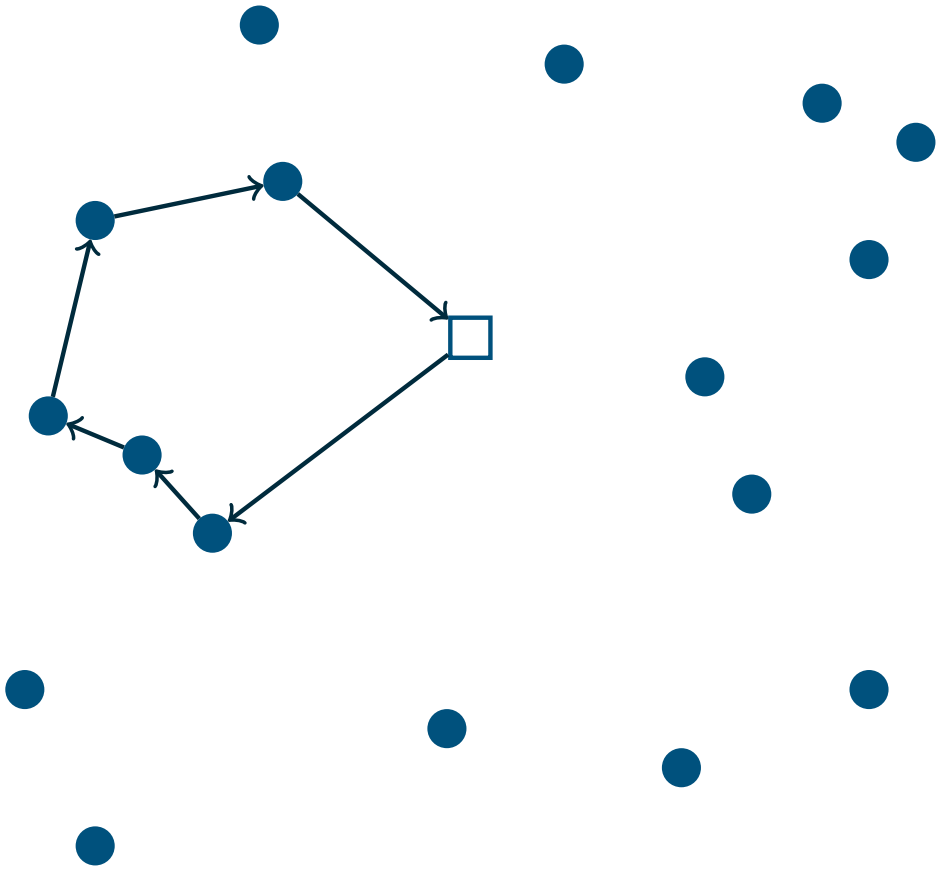

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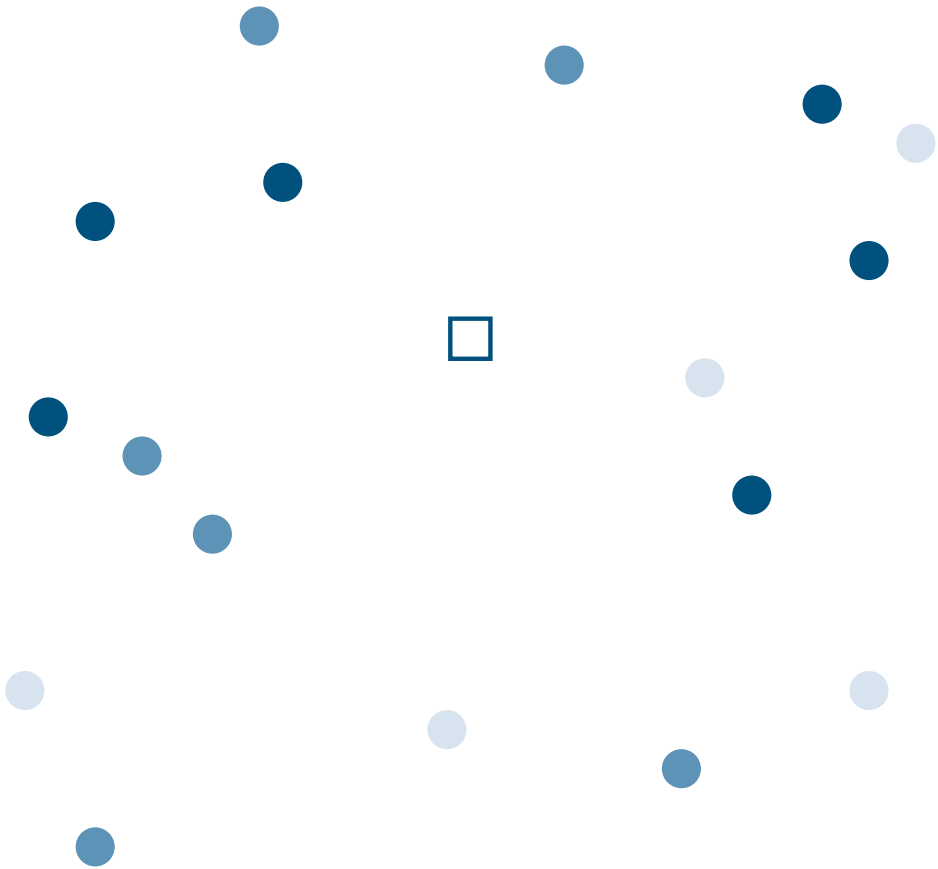
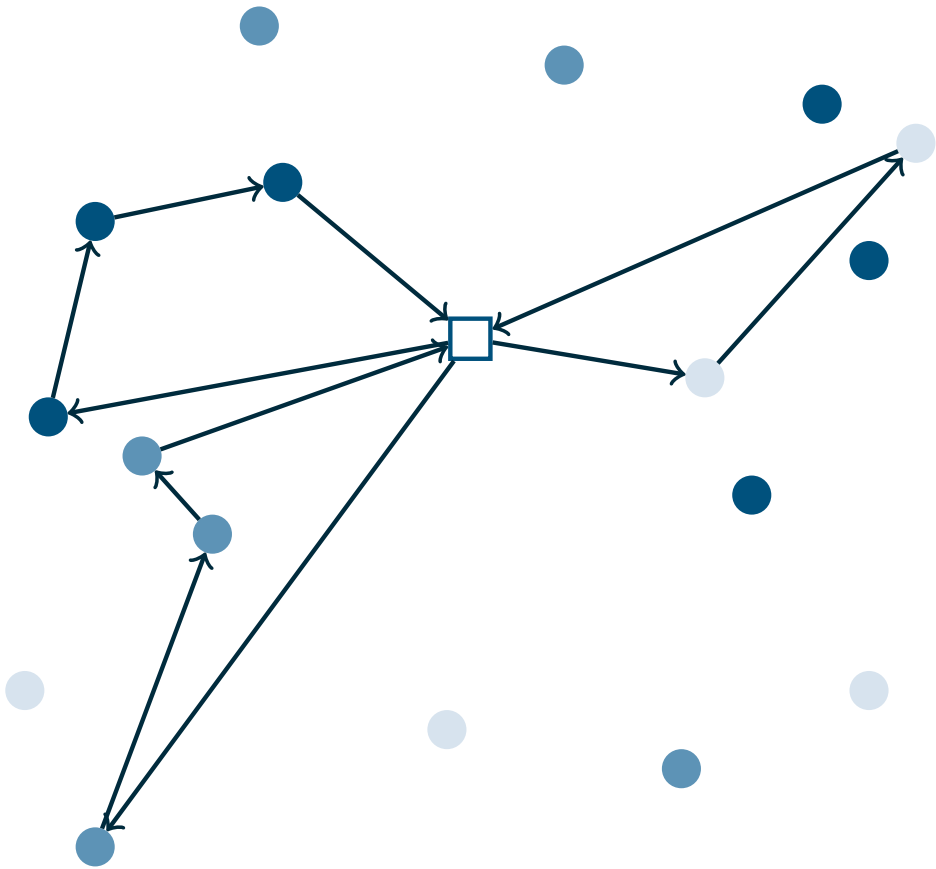


Imagine...

- 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

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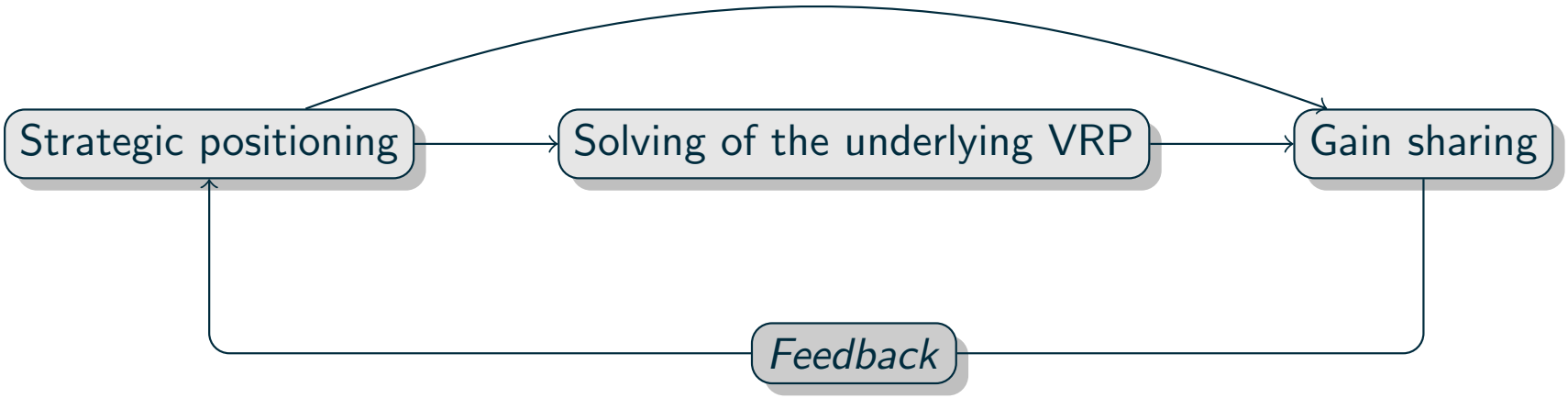
Global Result Collaboration

- 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



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

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Compensation for non-delivery (CND)

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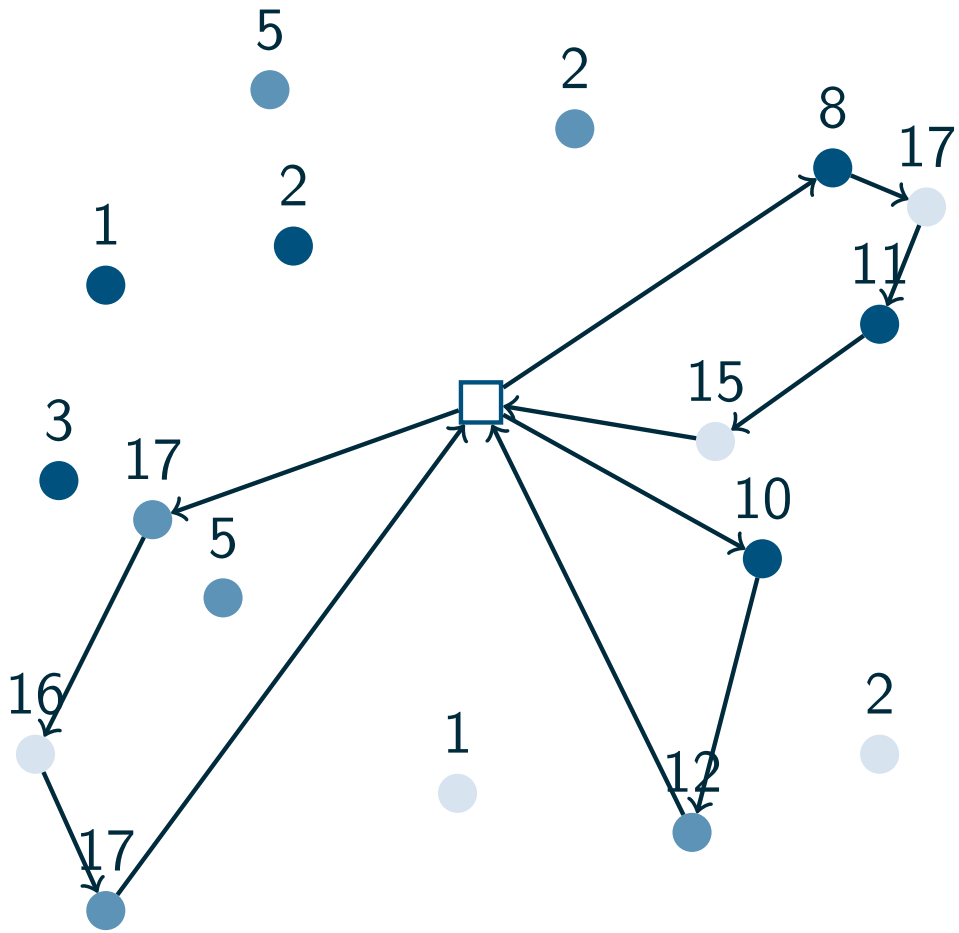
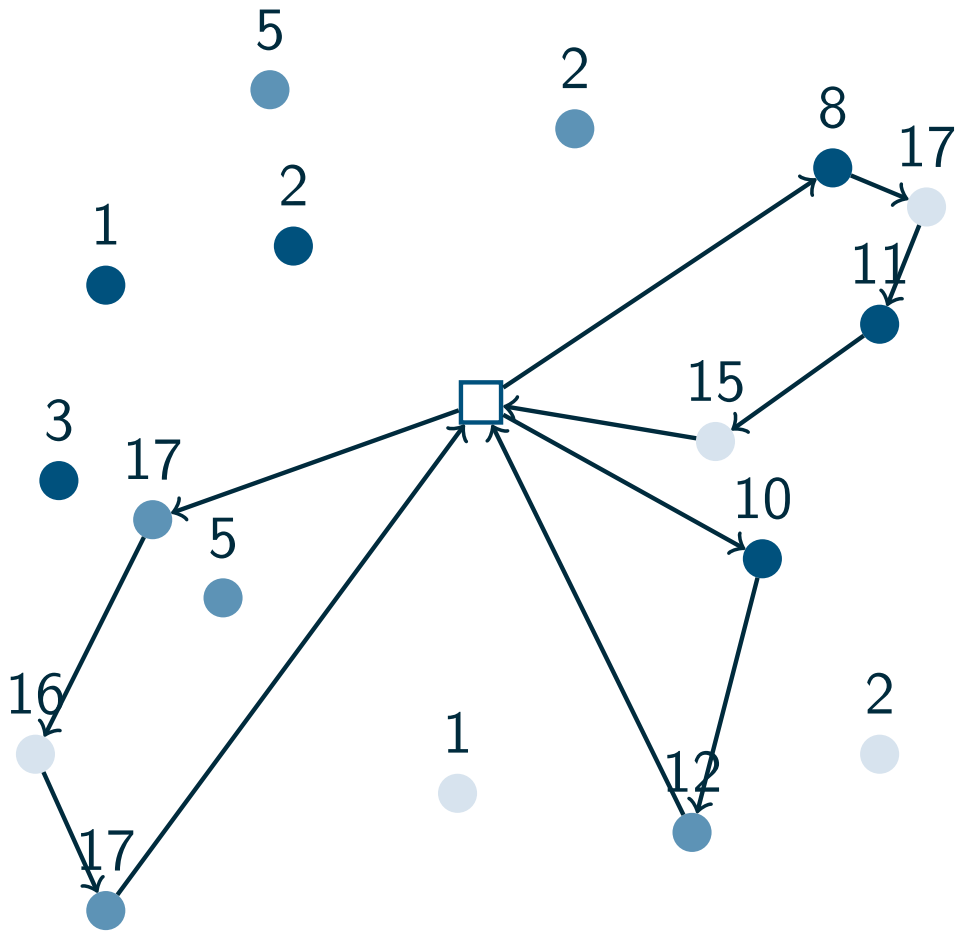


- Different CND for every client
- Clients with a higher cost are more likely to be part of the solution
- Significant differences in CND will pull the solution away from maximal efficiency in favour of the expensive clients
- Number of clients visited will lower

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)

Divide and Conquer

"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

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Shapley Value

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

- Put forward by the CO^3-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

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

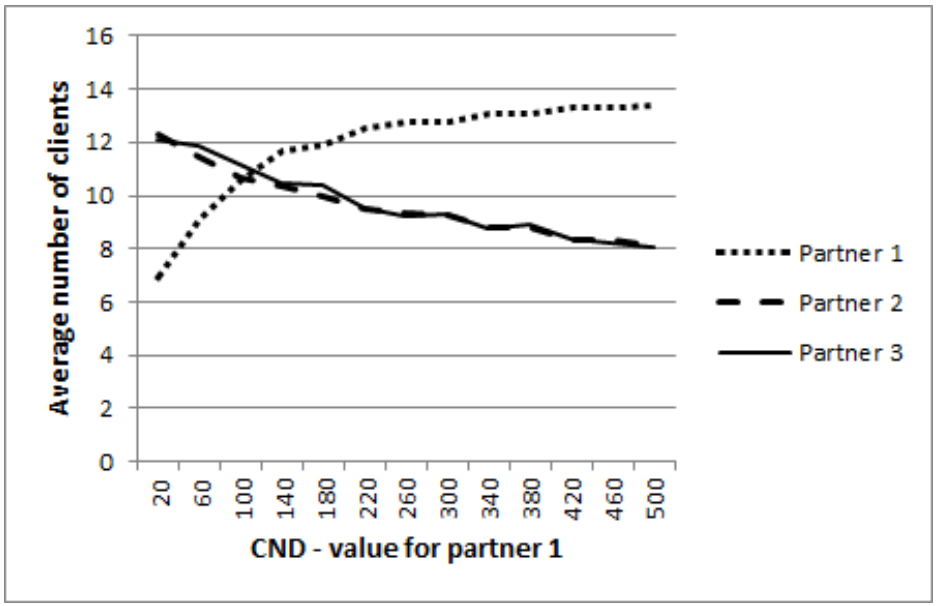
- Separable cost (M_i) + weighted division of remaining cost
- Only based on specific colSVRP parameters *(client location & CND policy)*

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

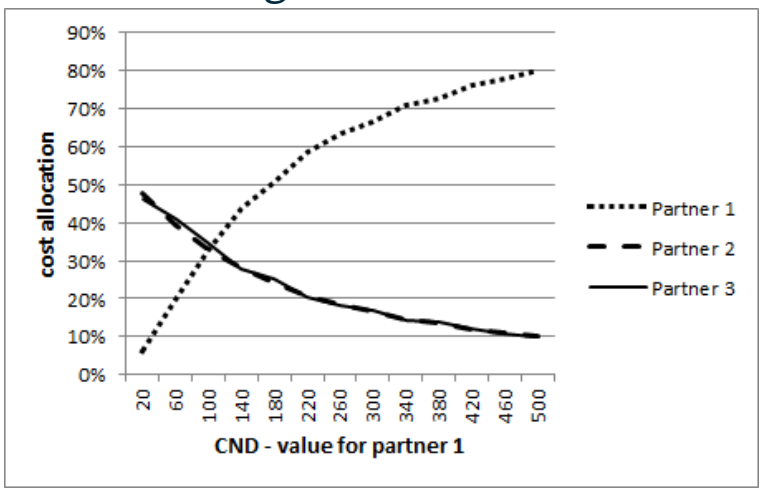
Client locations are generated randomly



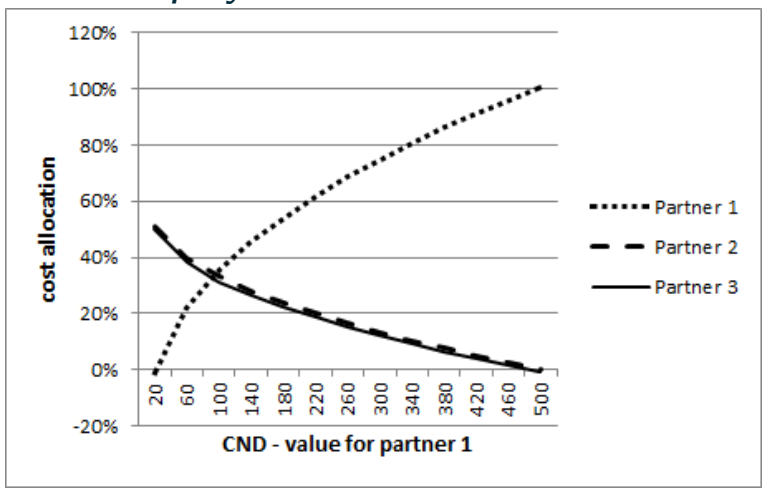
- If CND-values are the same, an equal number of clients is served
- Raising the CND makes your clients more important, more clients will be taken into the final solution

Impact of Compensation for non-delivery

CND-weighted cost allocation



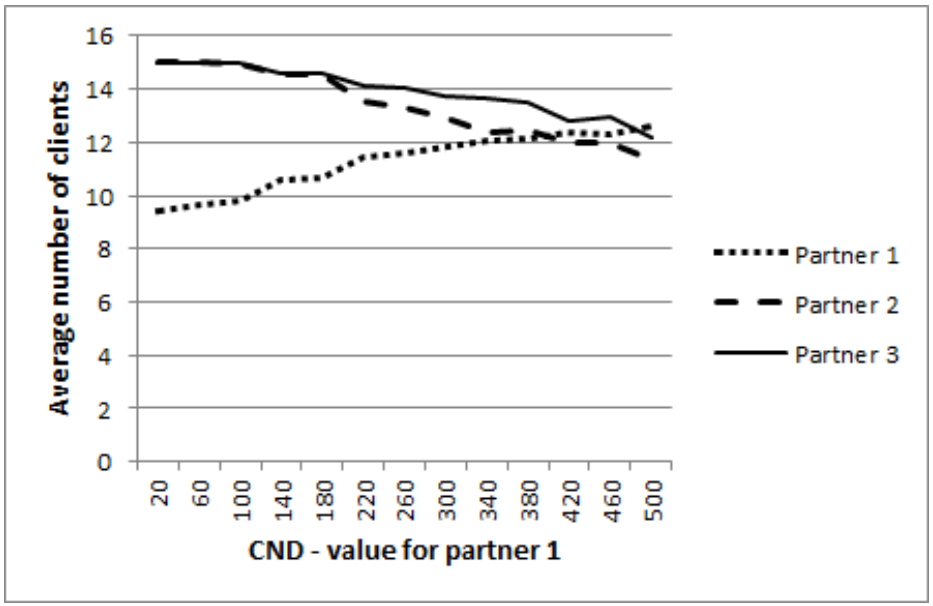
Shapley Value cost allocation



- Similar behaviour of both allocation methods
- Shapley punishes inflexibility more

Distance from depot

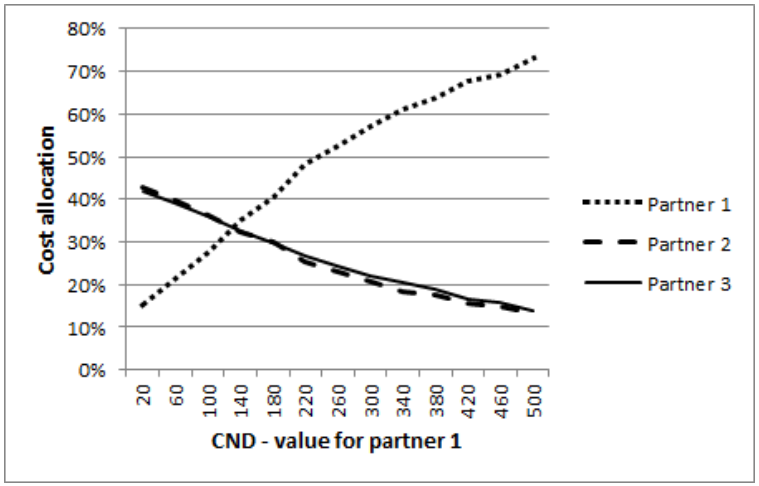
Clients of Partner 1 are located relatively far from the depot



- 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

CND-weighted cost allocation



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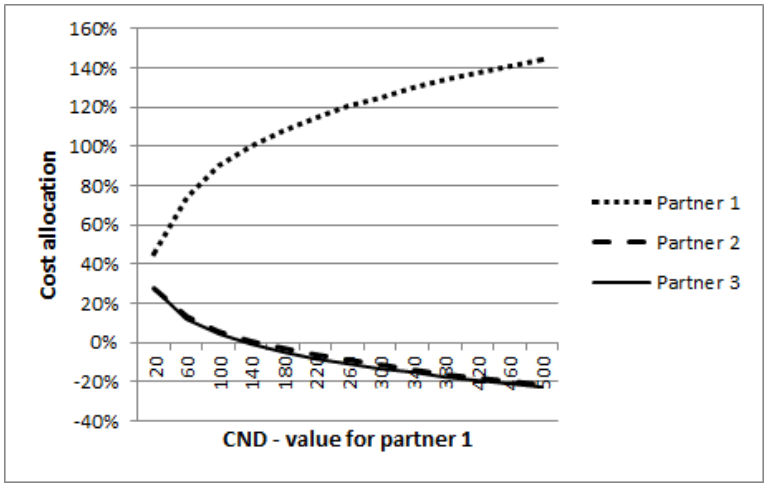
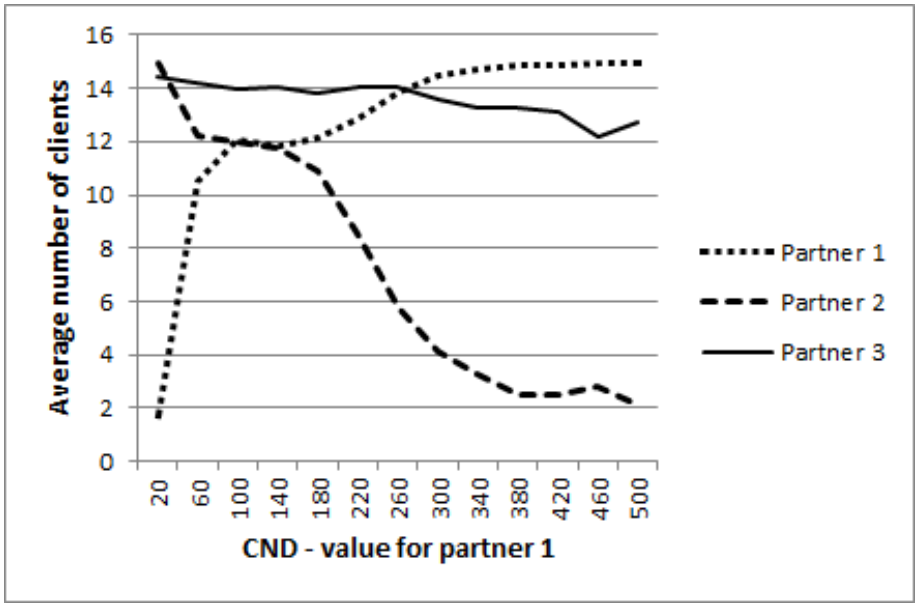


- Forcing the clients of partner 1 in the solution increases the coalition cost, which is penalized in both methods
- Due to non-monotonic increasing costs, allocations above 100% and below 0% can be found with Shapley

Client Clustering

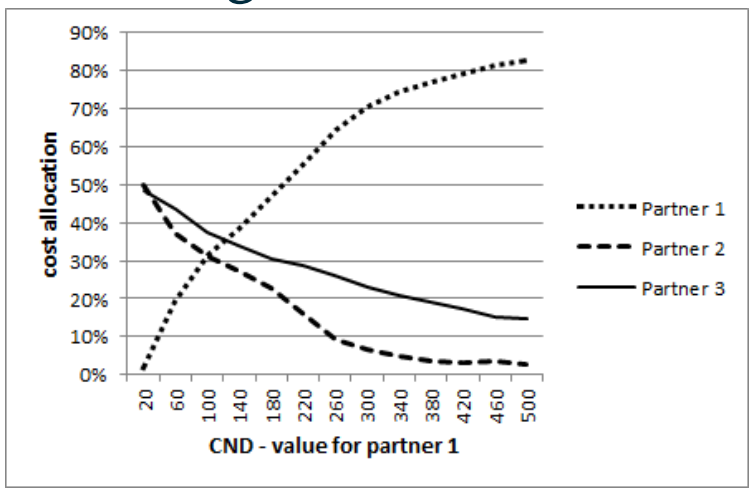
Clients belonging to the same partner are clustered in one region of the solution space. On average, clients of Partner 3 are located closer to the depot.



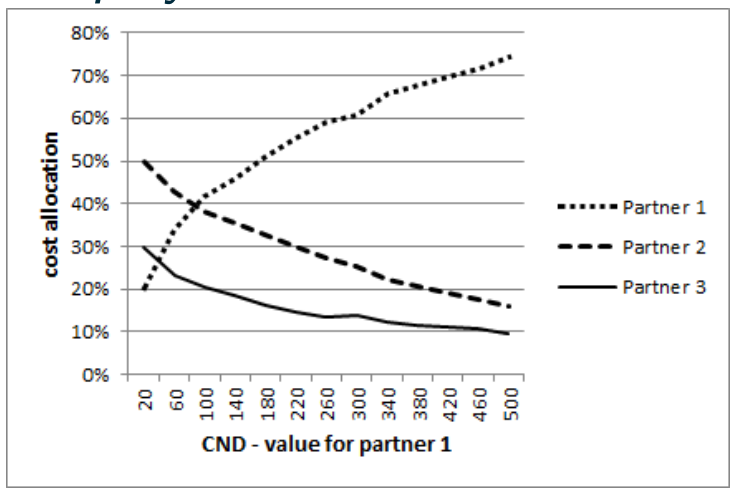
- The cluster closest to the depot is favoured *(see Scenario 2)*
- If clients are located further, they need to be significant expensive to be favoured
- Favouring one partner is at the expense of the furthest, flexible partner

Client Clustering

CND-weighted cost allocation



Shapley Value cost allocation



- CND-weighted method is based on the final routing solution. Less clients in the solution $\rightarrow$ lower cost (Partner 2)
- 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 ables to exploit new synergies
- A collaborative problem is more than the sum of the partners
- The behaviour of partners affects both optimal route ánd cost allocation
- The interaction between cost allocation and routing should not be neglected

To conclude

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

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