



University of Antwerp
Operations Research Group

ANT/OR

The Collaborative Selective Vehicle Routing Problem

Vehicle routing in a collaborative environment

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ORBEL 28 / January 30–31, 2014

Research supported by the Research Foundation - Flanders (FWO - Ph.D. fellowship) and the Interuniversity Attraction Poles (IAP) Programme initiated by the Belgian Science Policy Office (COMEX project)





Overview

The Selective Vehicle Routing Problem

Introduction to the Collaborative Environment

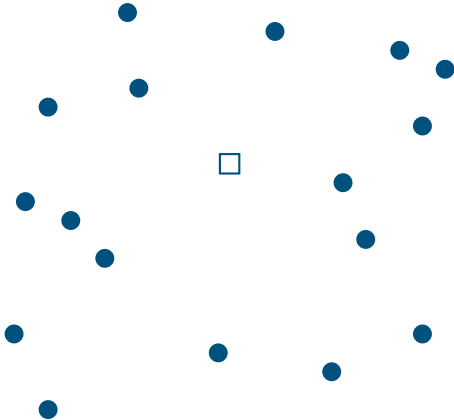
Solving of the Collaborative Problem

- Strategic positioning

- Gain Sharing (or Cost Allocation)

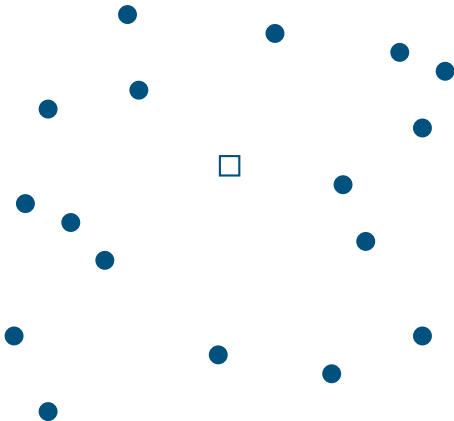
A simulation study

Concluding Remarks



Imagine...

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

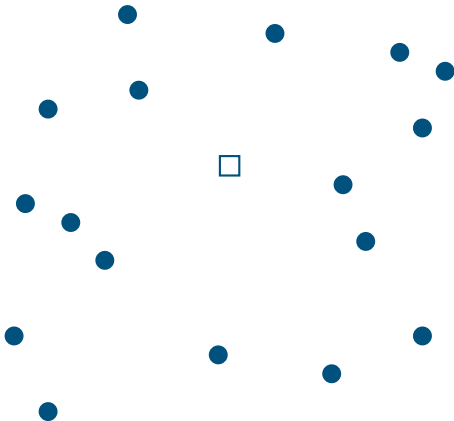


Imagine...

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But...

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



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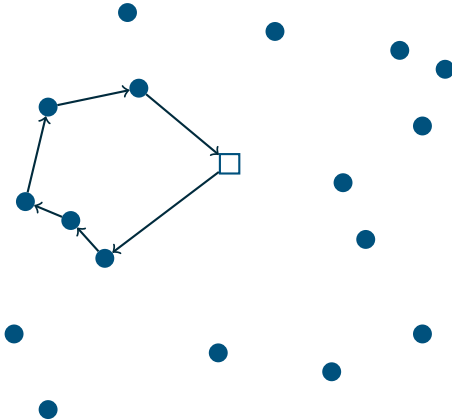
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Therefore...

- ▶ Only a limited number of clients can be served now



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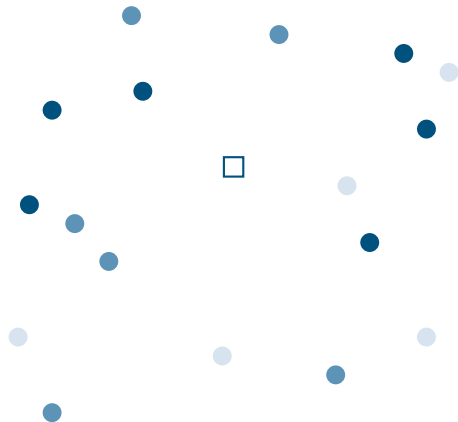
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The Collaborative Environment introduced

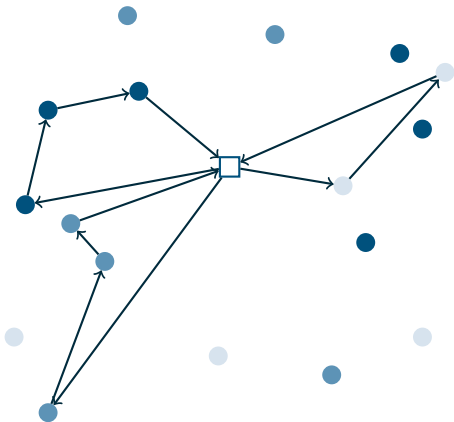


Imagine...

- ▶ 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

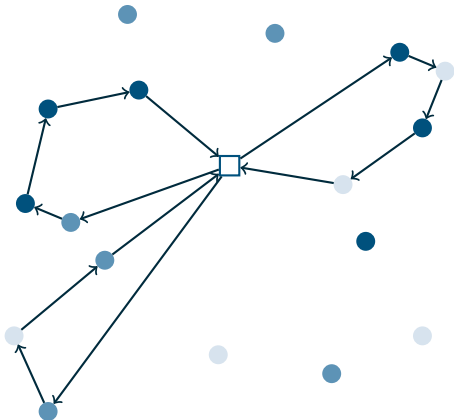
- ▶ 8 clients are served (2-3-3)

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

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Introduce Collaboration

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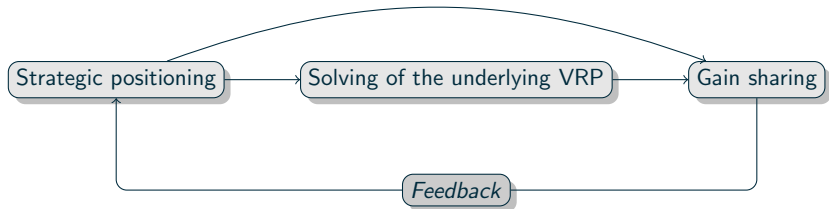
Global Result Collaboration

- ▶ 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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versus

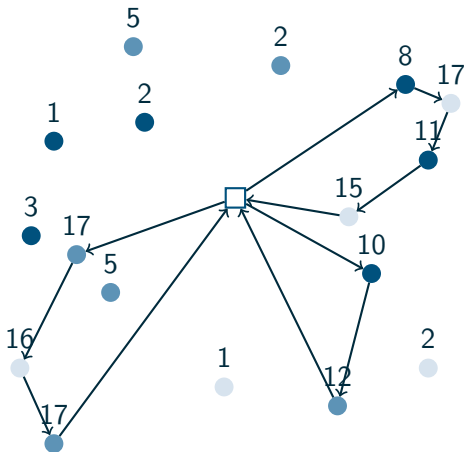
“All my (important) clients should be part of the solution”

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)



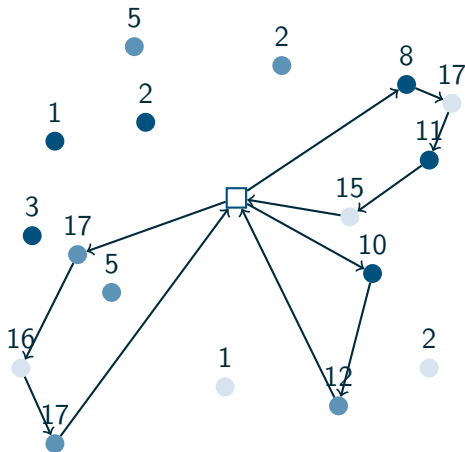
How do I behave in the coalition?



- ▶ 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)



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



Divide and Conquer

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

Shapley Value

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

- ▶ 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*)



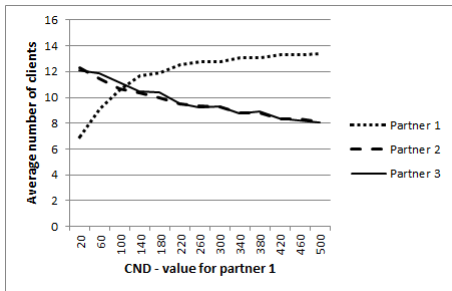
A simulation study

- ▶ 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

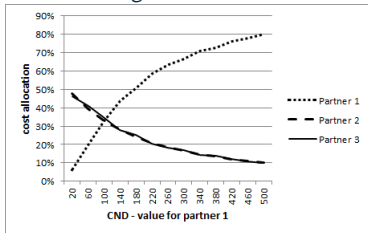


- ▶ If CND-values are the same, an equal number of clients is served
- ▶ Raising the CND makes your clients more important, more clients will be taken into the final solution

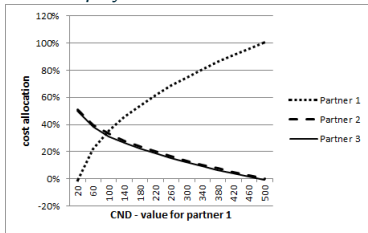


Impact of Compensation for non-delivery

CND-weighted cost allocation



Shapley Value cost allocation

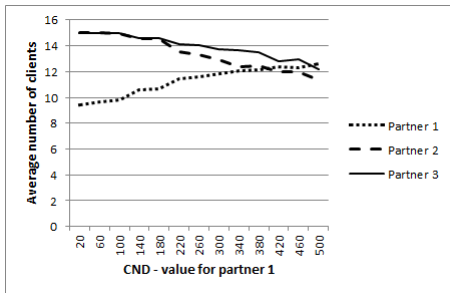


- ▶ Similar behaviour of both allocation methods
- ▶ Shapley punishes inflexibility more



Distance from depot

Clients of Partner 1 are located relatively far from the depot

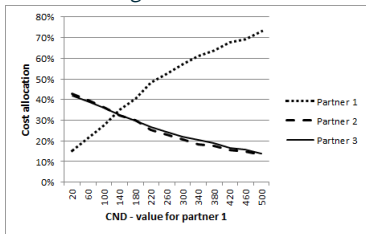


- ▶ If CND-values are the same, partners with more accessible clients will be favoured
- ▶ Unfavoured clients need to be significant expensive (high CND value) to make the longer trip valuable

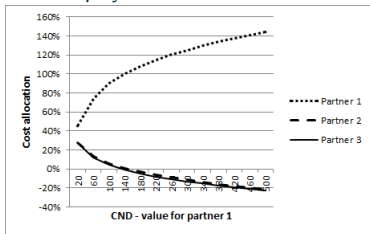


Distance from depot

CND-weighted cost allocation



Shapley Value cost allocation

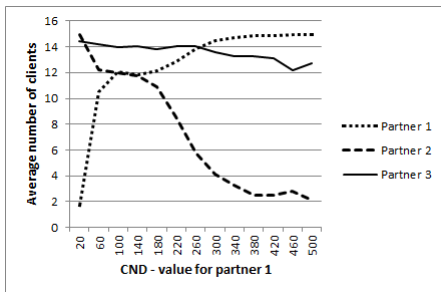


- ▶ Forcing the clients of partner 1 in the solution increases the coalition cost, which is penalized in both methods
- ▶ Due to non-monotonic increasing costs, allocations above 100% and below 0% can be found with Shapley



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.

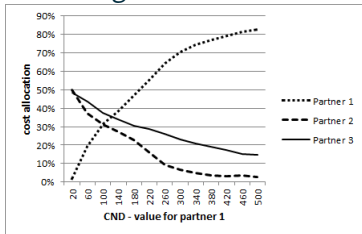


- ▶ The cluster closest to the depot is favoured (*see Scenario 2*)
- ▶ If clients are located further, they need to be significant expensive to be favoured
- ▶ Favouring one partner is at the expense of the furthest, flexible partner

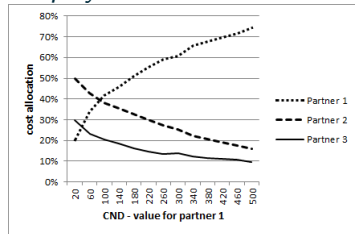


Client Clustering

CND-weighted cost allocation



Shapley Value cost allocation



- ▶ CND-weighted method is based on the final routing solution. Less clients in the solution → lower cost (Partner 2)
- ▶ Shapley Value is based on all sub-coalitions. Closer to the depot → higher stand-alone efficiency → 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

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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