



University of Antwerp  
Operations Research Group

ANT/OR

# Horizontal logistic cooperations

*Integration of individual partner objectives in  
multi-partner logistic optimisation models*

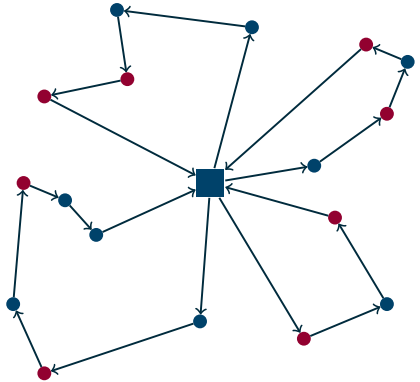
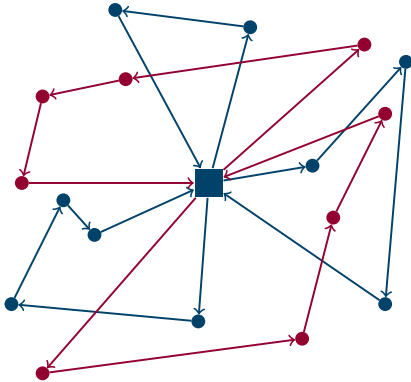
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University of Antwerp – ANT/OR Operations Research Group  
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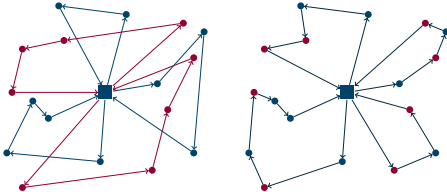
# Collaborative vehicle routing





# Traditional approach

- ▶ Compare logistic planning with and without collaboration
  - ▶ Stand-alone vs. complete collaboration
  - ▶ Based on a global KPI
    - usually **min. total cost**



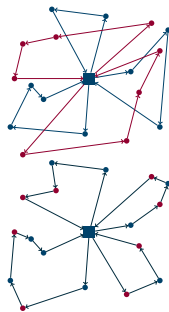
- ▶ **proof of concept = double-digit savings**
  - ▶ In theory and in real life
  - ▶ Cost and CO<sub>2</sub> emissions



# Research Question

## ► Drawbacks of current approach

- The multi-partner problem characteristics are ignored.
- The workload and costs should be allocated back to the individual partners.
- How to define what is best for the coalition?  
→ *What will be the objective function?*
- Is what is best for the coalition also the best for all partners?



**Can we develop an optimisation procedure for solving collaborative routing problems that considers (also) the individual partner interests?**



# Individual partner interests

**How to make sure that a solution for the group is accepted as a good solution by each partner?**

- ▶ Literature review
  - ▶ Compensation mechanism ( $\rightarrow$  *auction based models*)
  - ▶ Cost allocation as a post-processing step
  - ▶ Cost allocation as a model constraint
  - ▶ not addressed at all ...

## **Our approach:**

Including the interests of the individual partner in the objective function of the logistic optimisation model.



# Coalition objective vs. Partner objective

## ▶ Coalition level objective

- ▶ What is the most desired outcome for the coalition as a whole
- ▶ One (set of) objective(s) that all partners agree on
- ▶ *What brings all these companies around the same table*

## ▶ Partner level objective

- ▶ Which outcome is preferred by each of the individual partners
- ▶ One (set of) objective(s) per partner
- ▶ Possibly conflicting interests

**How to deal with all these (levels of) objectives?**

→ Increasing *complexity*

→ To obtain the cost, a *cost allocation method* is to be integrated in the optimisation procedure



# A three-step solution approach

## 1. **Solve the problem to coalition efficiency**

- ▶ Given the coalition objective, what is the best this coalition can achieve?

## 2. **Define an acceptable deviation**

- ▶ How much are we willing to sacrifice in favour of individual interests?
- ▶ Neighbourhood  $\mathcal{N}_{CE}$

## 3. **Explore $\mathcal{N}_{ce}$ given the individual partner objectives**

- ▶ What do the alternative solutions mean for the individual partners?



# A concrete example

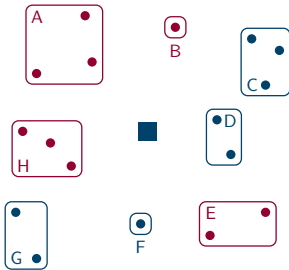
## ▶ **Clustered Vehicle Routing Problem**

→ *model courier company*

- ▶ Customers are grouped into clusters
- ▶ One vehicle serves multiple zones
- ▶ *Sorting* is decoupled from *routing*
- ▶ Reduction of problem complexity

## ▶ **Strong cluster constraints**

- ▶ Serve all clients with a given fleet of vehicles
- ▶ Visit clients of each zone sequentially in the same path



A vehicle trip is represented by a sequence of zones





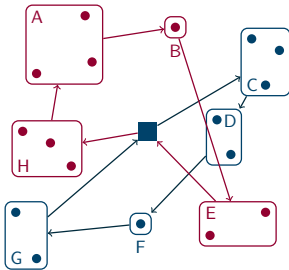
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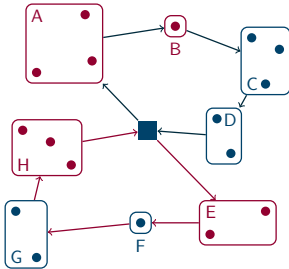
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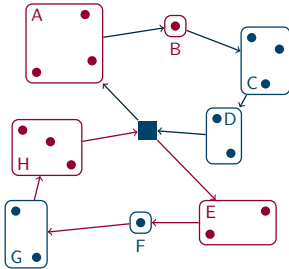
- Serve all clients with a given fleet of vehicles
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**How to define this collaborative logistic optimisation problem?**



# Problem definition



## ► Coalition objective

- Minimise the total logistic cost

- $F_c(x) = \sum_{p \in N} \left( \sum_{(i,j) \in E} \sum_{k \in K} d_{ij} x_{ijk} \right)_p$

## ► Partner objectives

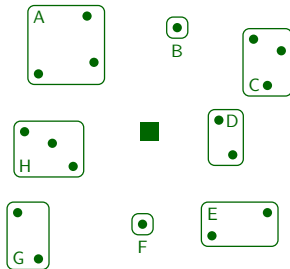
- Minimize the allocated cost
- Given predefined cost allocation method
- $\forall p \in N : F_p(x) = \psi_p$



## Step 1: solve at coalition level

- ▶ Use any non-collaborative technique to solve aggregated problem to optimality
- ▶ Only consider the coalition objective

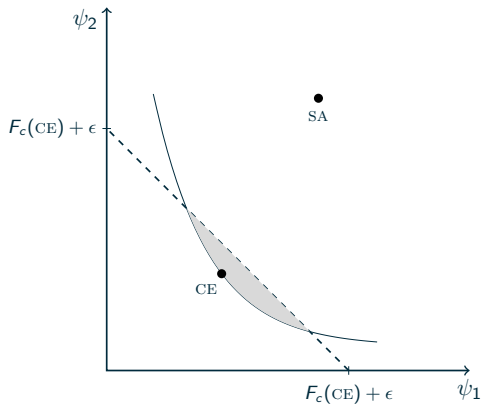
$$F_c(x) = \sum_{p \in N} \left( \sum_{(i,j) \in E} \sum_{k \in K} d_{ij} x_{ijk} \right)_p$$





## Step 2: Define $\mathcal{N}_{\text{CE}}$

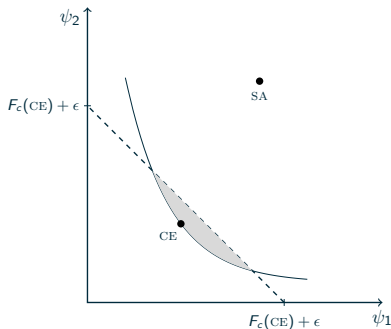
$$\mathcal{N}_{\text{CE}} = \{x \mid d(x, \text{CE}) \leq \epsilon\}$$





## Step 3: Explore $\mathcal{N}_{\text{CE}}$

- ▶ Explore alternative **cluster configurations**
- ▶ Only retain solutions that are Pareto efficient with respect to the partner objectives
- ▶ Multi-objective optimisation



- ▶ Solution evaluation is expensive
  - ▶ Pareto dominance
  - ▶ Cost allocation
- ▶ Focus on **interesting** part of Pareto frontier
- ▶ Reduce complexity



# Experimental Results

Results for  $\alpha = 5\%$

instance					grand coalition			partner 1			partner 2			Pareto set	
n	k	C	V	p	total sa	cost ce	max. profit	ce	profit min	max	ce	profit min	max	size	
33	6	11	2	2	676	562	17%	24%	16%	27%	6%	-10%	16%	4	X
44	6	15	2	2	811	729	10%	-1%	-2%	3%	19%	18%	23%	3	X
45	6	15	3	2	776	712	8%	14%	2%	16%	-2%	-9%	8%	8	X
45	7	15	3	2	818	664	19%	<b>13%</b>	13%	13%	<b>29%</b>	29%	29%	1	
46	7	16	3	2	801	664	17%	18%	16%	24%	15%	1%	17%	11	X
48	7	16	3	2	836	683	18%	15%	15%	19%	<b>23%</b>	16%	23%	4	
53	7	18	3	2	817	651	20%	17%	16%	21%	<b>24%</b>	16%	24%	5	
54	7	18	3	2	873	724	17%	15%	6%	16%	20%	13%	30%	8	X
55	9	19	3	2	795	653	18%	<b>14%</b>	11%	14%	<b>25%</b>	25%	25%	2	
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63	9	21	3	2	1029	865	16%	10%	2%	9%	26%	25%	29%	4	X
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Optimal coalition solution is almost never optimal for all partners.



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Optimal coalition solution is often non-optimal for all partners (X).



## To conclude

- ▶ Horizontal cooperation can be profitable.
  - ▶ Small deviations in coalition objective can lead to large differences for individual partners.
  - ▶ Optimal coalition solution is almost never optimal for all partners.
  - ▶ Optimal coalition solution is often non-optimal for all partners (X).
- 
- ▶ Including individual partner interest as objectives in the logistic optimisation model for horizontal cooperation is clearly a good idea.
  - ▶ We presented an integrated solution framework to integrate both levels of objectives.
    - ▶ **Coalition objective**  
What is the main goal of the coalition as a whole?
    - ▶ **Partner objectives**  
What do individual partners want?



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