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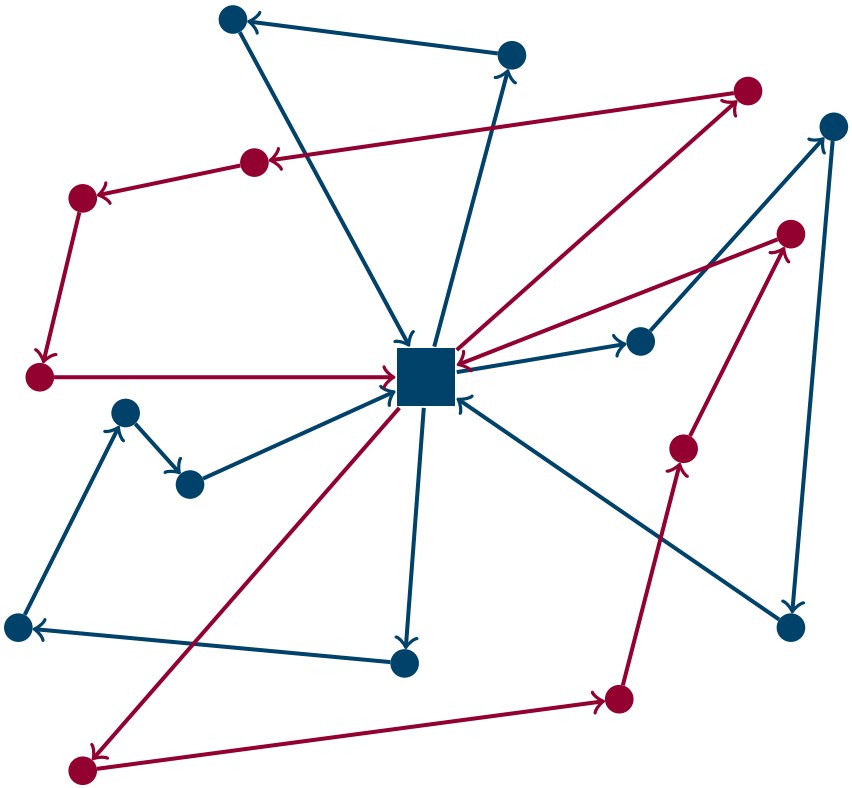
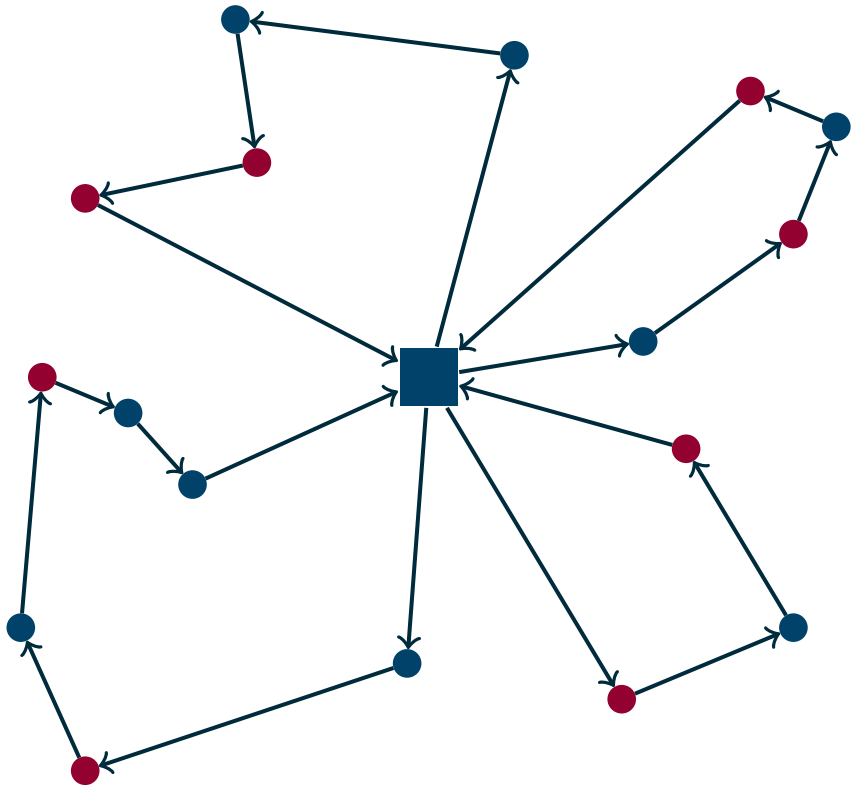
Research supported by the Research Foundation - Flanders (FWO - Ph.D. fellowship) and the Interuniversity Attraction Poles (IAP) Programme initiated by the Belgian Science Policy Office (COMEX project)

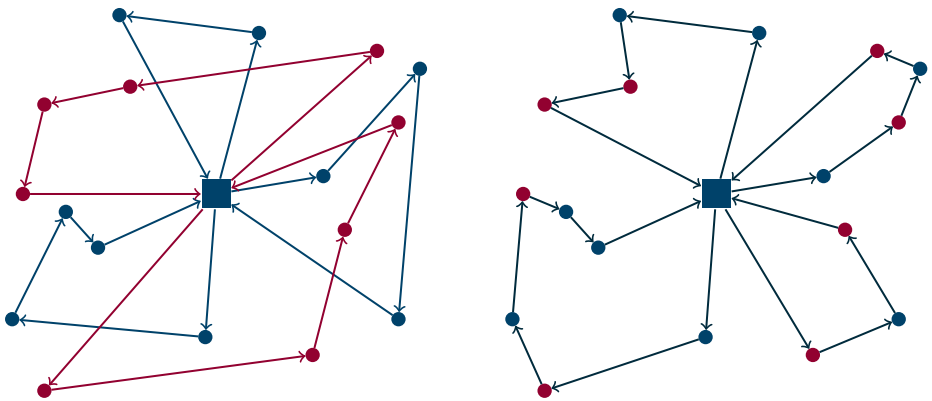
Collaborative vehicle routing





Traditional approach

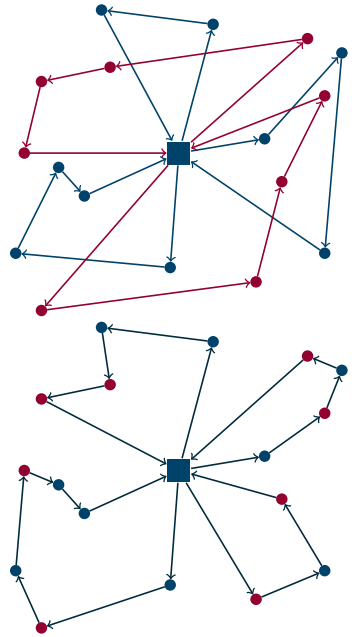
- Compare logistic planning with and without collaboration
  - Stand-alone vs. complete collaboration
  - Based on a global KPI
    $\rightarrow$ usually **min. total cost**



- **proof of concept = double-digit savings**
  - In theory and in real life
  - Cost and CO_2 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?
    $\rightarrow$ *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 *(→ 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

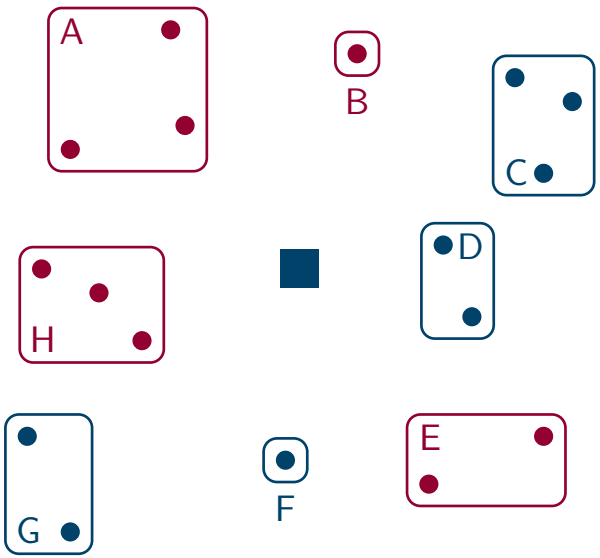
How to deal with all these (levels of) objectives?

→ *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 $\mathcal{N}_{\mathrm{CE}}$
3. **Explore $\mathcal{N}_{\mathbf{ce}}$ given the individual partner objectives**
   - What do the alternative solutions mean for the individual partners?

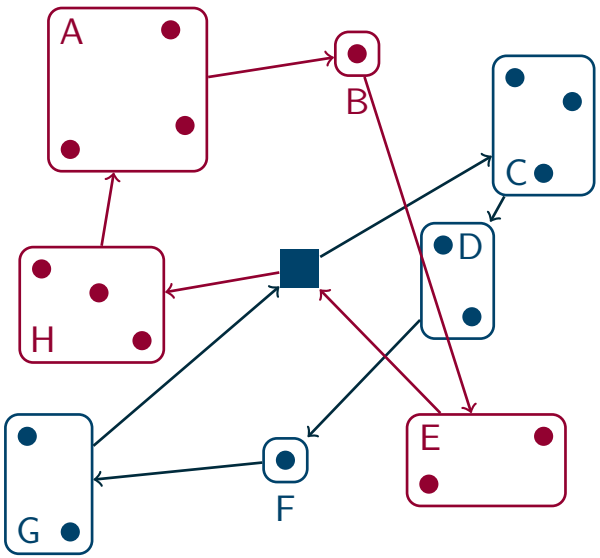
A concrete example



- **Clustered Vehicle Routing Problem**
  $\rightarrow$ *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

A concrete example



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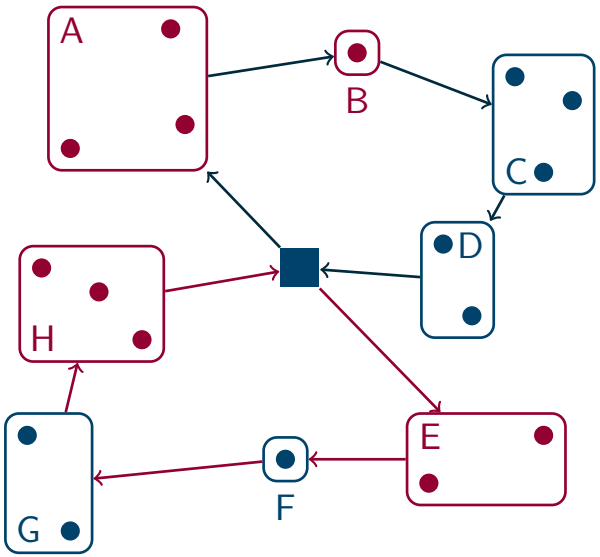

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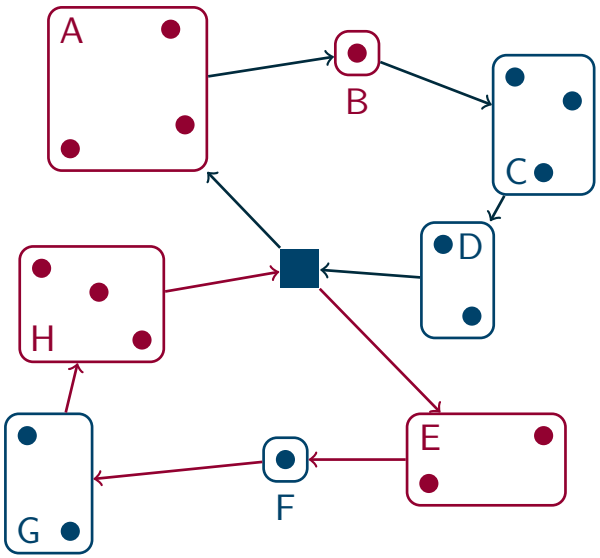
How to define this collaborative logistic optimisation problem?

Problem definition

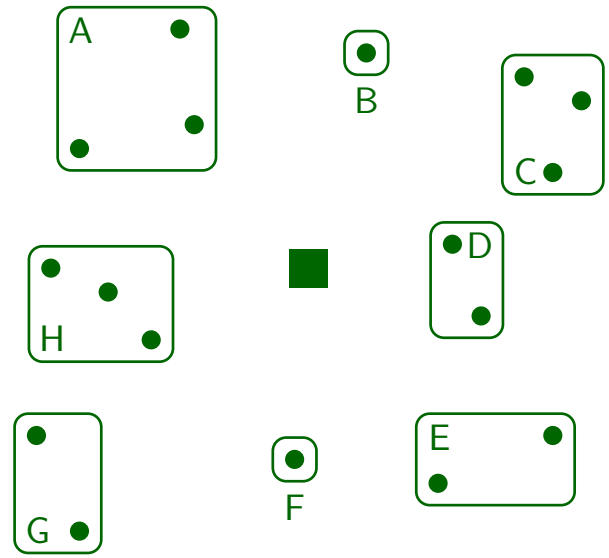


- **Coalition objective**
  - Minimise the total logistic cost
  - $F_c(x) = \sum_{p \in N} \left(\sum_{(i,j) \in E} \sum_{k \in K} d_{ij} x_{ijk} \right)_p$
- **Partner objectives**
  - Minimize the allocated cost
  - Given predefined cost allocation method
  - $\forall p \in N : F_p(x) = \psi_p$

Step 1: solve at coalition level

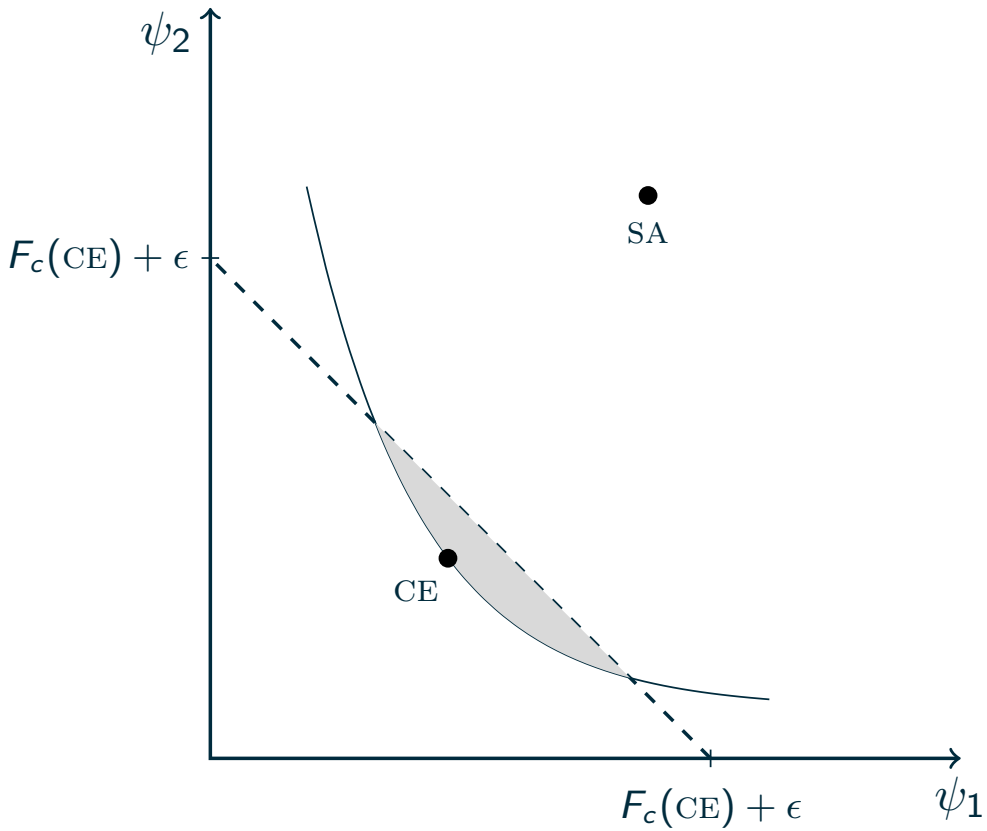
- Use any non-collaborative technique to solve aggregated problem to optimality
- Only consider the coalition objective

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



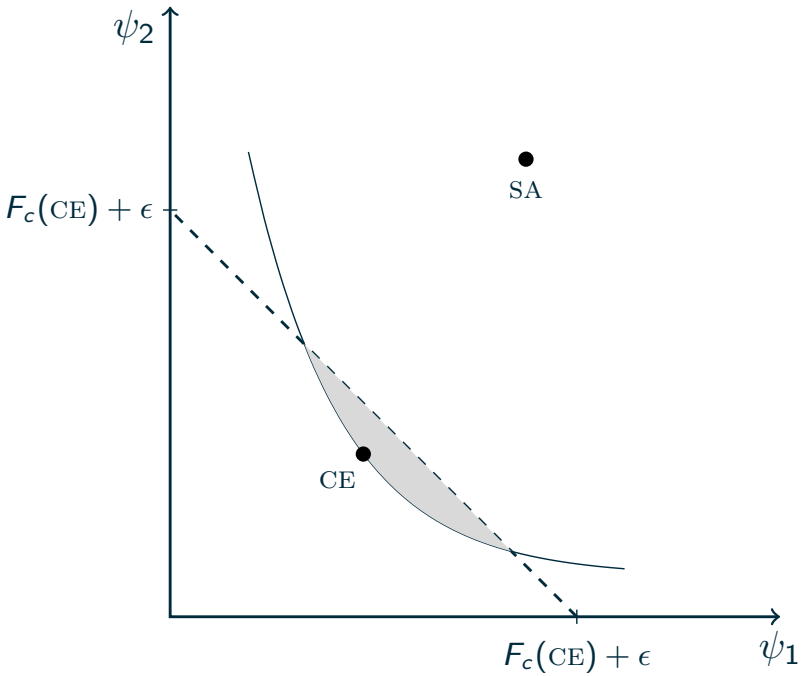
Step 2: Define $\mathcal{N}_{\mathrm{CE}}$

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



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	
					total cost			profit			profit				
n	k	C	V	p	sa	ce	max. profit	ce	min	max	ce	min	max	size	
33	6	11	2	2	676	562	17%	24%	16%	27%	6%	-10%	16%	4	✗
44	6	15	2	2	811	729	10%	-1%	-2%	3%	19%	18%	23%	3	✗
45	6	15	3	2	776	712	8%	14%	2%	16%	-2%	-9%	8%	8	✗
45	7	15	3	2	818	664	19%	**13%**	13%	13%	**29%**	29%	29%	1	
46	7	16	3	2	801	664	17%	18%	16%	24%	15%	1%	17%	11	✗
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80	10	27	4	2	1197	974	19%	36%	26%	38%	-1%	-8%	6%	17	✗

Horizontal cooperation can be profitable.

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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 (✗).

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 (✗).

- 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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