

Benefits of Horizontal Cooperation in Supply Chains

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Introduction

➡ **Horizontal cooperation** is *"an active cooperation between two or more firms that operate on the same level of the supply chain and perform a comparable logistics function"*. (Cruijssen et al., 2006)

➡ **Henkel, Colgate and Reckitt Benckiser:** 800,000 pallets per year and a unique warehouse.

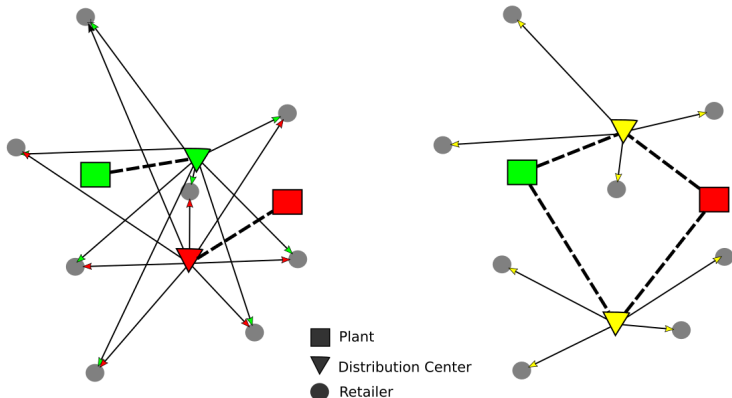
- The vehicle loading rate improved from 75% to 95%.
- The number of trips reduced by 20% (about 800 trucks/year).
- The inventory reduced by 20%.

➡ **Procter&Gamble and Tupperware:** to improve the cargo density (weight and volume) between Belgium and Greece.

- Reduction of 17% on total transportation costs.
- 150,000 truck-km and 200 tons of CO₂ saved in the first year.

➡ Horizontal cooperation offers several **benefits**.

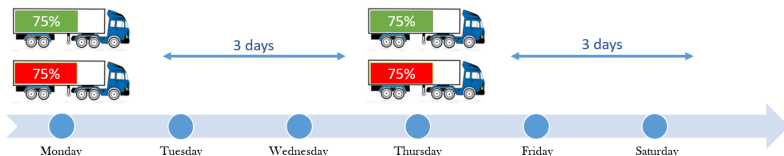
Benefit 1: More DCs and Shorter Distances



- ① Access to more, better positioned, DCs.
- ② But typically less DCs in total.
- ③ Leading to shorter distances (cost and CO₂).
- ④ And shorter lead time (proportional to distances).

Benefit 2: Improved Vehicle Loading

STAND ALONE CASE



COOPERATIVE CASE



- ① Improved vehicle loading rate.
- ② Lower number of deliveries (reduced transportation cost).
- ③ Higher delivery frequency (but less vehicles coming).
- ④ Lower inventory level at retailers.

Barriers to Horizontal Cooperation

- ▣ A first barrier to cooperation is the **assessment of benefits**.
 - ① **Cost** reductions go from 5% to about 30% (Hageback and Segerstedt, 2004; Frisk et al., 2010).
 - ② Also a high variation in the **emissions** reductions due to cooperation, between 8% and 33% (Soysal et al., 2018).
- ▣ The cooperation requires **confidence, trust, and information sharing** between the partners involved in the process.
- ▣ A fair **gain sharing** mechanism is essential.
- ▣ Cooperative solutions should take into account the **individuality** and the expectations of each partner.

Research Objectives

⇒ Our main objective is to present valuable managerial insights to help companies **assessing the potential economical and environmental benefits** they can get when cooperating with specific partners, **as a function of their characteristics**.

⇒ Specifically, we study the impact of:

- ① The operating **costs** (DC opening, ordering, holding costs).
- ② The **market** (demand variability, geographical distribution).
- ③ The **partners** (number of partners, partners' expectations).

⇒ We use a **location-inventory model** to decide the locations of the DCs, the delivery network, and the inventory decisions.

In this **presentation**, we present three related papers.

Assessing the Benefits of Horizontal Cooperation using a Location-Inventory Model

Thomas Hacardiaux, Jean-Sébastien Tancrez

- Hacardiaux, T., Tancrez, J. S. (2018). Assessing the benefits of horizontal cooperation using a location-inventory model. CORE DP No. 2018014. Université catholique de Louvain, Center for Operations Research and Econometrics.
- Under revision for **Operational Research Journal**

Location-Inventory Model

We assess the cooperation **benefits** from sharing a joint supply network, and the impact of partners and market characteristics.

$$\begin{aligned}
 \min \quad & \sum_d F_d y_d + \sum_{d,r} T D_{dr} \frac{\Lambda_r}{Q_{dr}} x_{dr} + \sum_{d,r,i} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} \\
 & + \sum_{d,i} \sqrt{2 K_d^i h_d^i} v_{1d}^i + \sum_{d,r,i} H_r^i z_\alpha \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_{d,i} h_d^i z_\alpha \sqrt{L T_d^i} v_{2d}^i \\
 \text{s.t.} \quad & \sum_r \lambda_r^i (x_{dr})^2 \leq (v_{1d}^i)^2 \quad \forall d, i \\
 & \sum_r (\sigma_r^i)^2 (x_{dr})^2 \leq (v_{2d}^i)^2 \quad \forall d, i \\
 & \sum_d x_{dr} = 1 \quad \forall r \\
 & x_{dr} \leq y_d \quad \forall d, r \\
 & v_{1d}^i, v_{2d}^i \geq 0 \quad ; \quad x_{dr}, y_d \in \{0, 1\} \quad \forall i, d, r
 \end{aligned}$$

► *Transportation costs are proportional to the number of vehicles (not flow).*

Research Objective and Experiments

- ① We **assess the cooperation benefits** of a joint supply network, integrating **location decisions** and **inventory decisions** (and demand uncertainty).
- ② We perform **27,180 experiments** to reinforce the validity of our results, varying several key parameters.
 - Facility opening cost,
 - Vehicle capacity,
 - Inventory holding cost,
 - Ordering cost,
 - Demand variability,
 - Market size (distances),
 - Number of partners.

Synergy Value

➡ The average (relative) benefit is around 22.4%.

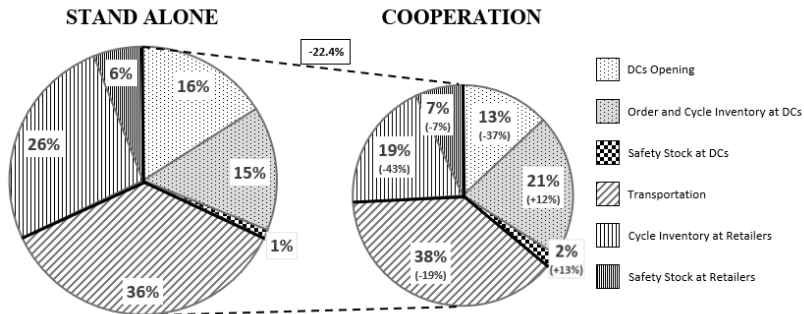
F	C	CV = 0,4			CV = 1			Average
		H = 0,25	H = 0,5	H = 1	H = 0,25	H = 0,5	H = 1	
1000	10%	19.70%	14.86%	15.87%	18.95%	16.80%	14.73%	16.82%
		5.20 3.23	6.23 4.27	7.37 4.87	5.17 3.37	6.50 4.10	7.77 5.03	6.37 4.14
		0.94 0.97	0.95 0.98	0.96 0.99	0.94 0.97	0.95 0.98	0.96 0.99	0.95 0.98
	40%	21.91%	20.85%	19.09%	21.19%	19.76%	17.50%	20.05%
		3.77 2.53	4.87 3.00	5.83 3.60	3.37 2.50	4.93 3.13	6.03 3.77	4.80 3.09
		0.86 0.92	0.85 0.93	0.86 0.94	0.86 0.92	0.85 0.93	0.86 0.95	0.86 0.93
	70%	23.60%	22.61%	21.11%	22.68%	21.47%	19.37%	21.81%
		3.73 1.93	4.23 2.50	5.20 3.00	3.13 1.97	4.30 2.63	5.60 3.10	4.36 2.52
		0.75 0.89	0.74 0.88	0.75 0.89	0.75 0.87	0.74 0.88	0.74 0.89	0.75 0.88
	100%	25.55%	24.46%	23.07%	24.34%	23.03%	21.00%	23.57%
		3.53 1.50	4.07 1.97	4.80 2.27	2.90 1.60	4.10 2.17	5.23 2.70	4.11 2.03
		0.54 0.72	0.51 0.71	0.50 0.70	0.53 0.70	0.50 0.68	0.50 0.68	0.51 0.70
4000	10%	20.54%	18.82%	19.11%	19.88%	18.13%	18.33%	19.14%
		2.13 1.03	2.00 1.57	2.23 2.33	2.03 1.10	2.00 1.67	2.43 2.37	2.14 1.68
		0.97 0.99	0.97 0.98	0.97 0.98	0.97 0.98	0.97 0.98	0.96 0.98	0.97 0.98
	40%	26.11%	23.70%	22.00%	25.18%	22.47%	20.52%	23.33%
		2.20 1.07	2.17 1.13	2.00 1.33	2.10 1.00	2.03 1.10	2.07 1.43	2.09 1.18
		0.88 0.96	0.89 0.97	0.90 0.95	0.88 0.96	0.89 0.97	0.89 0.95	0.89 0.96
	70%	28.85%	26.62%	24.62%	27.80%	25.17%	22.78%	25.97%
		2.20 1.00	2.33 1.00	2.07 1.13	2.40 1.00	2.20 1.00	2.00 1.20	2.20 1.06
		0.78 0.93	0.78 0.93	0.79 0.92	0.78 0.93	0.78 0.93	0.79 0.91	0.78 0.92
	100%	30.62%	28.63%	26.70%	29.57%	27.06%	24.60%	27.86%
		2.40 1.20	2.33 1.00	2.10 1.10	2.40 1.33	2.33 1.07	2.03 1.07	2.27 1.13
		0.58 0.79	0.55 0.77	0.56 0.76	0.56 0.78	0.55 0.77	0.56 0.75	0.56 0.77
	Average	24.61%	22.57	21.45%	23.70%	21.74%	19.85%	22.40%
		3.15 1.69	3.53 2.05	3.95 2.45	2.94 1.73	3.55 2.11	4.15 2.58	3.55 2.10
		0.79 0.89	0.78 0.89	0.78 0.89	0.78 0.89	0.78 0.89	0.78 0.88	0.78 0.89

Cooperation Benefits

➡ The cooperation benefits come from:

- ① **Shared DCs**, their total number is reduced.
- ② **Transportation**, reduced distances, efficient vehicle loading.
- ③ **Retailers cycle inventory**, more frequent deliveries.
- ④ **Retailers safety stocks**, reduced lead times.

➡ But, **inventory at DCs and ordering** costs increase.



Conclusion - Managerial Insights (1/2)

- ➡ We find an average synergy value of **22.4%** (14.7% to 30.6%).
 - ① **Companies open 2.10 DCs** on average (1.77 DCs for each stand-alone company), reducing distances by 10.5%.
 - ② Cooperation allows to **improve the average vehicle loading rate, by 11%** on average (from 78% to 89%).
- ➡ Companies have **stronger incentives** to cooperate when:
 - ① Opening costs are high.
 - ② Companies have large inefficiently loaded vehicles.
 - ③ Companies transport small cheap products.
 - ④ Order cost is low.
 - ⑤ The demand variability is low.

Conclusion - Managerial Insights (2/2)

➡ The impact of cooperation **for retailers** is significant:

- ➊ **Inventory cost** is reduced by 43%.
- ➋ The **delivery frequency** for a product is doubled.
- ➌ **Less vehicles** come to the retailer's door.

➡ The addition of new partners allows an increase of the average benefits to **31.2%** and **36%** with 3 and 4 partners, respectively.

➡ **The possibility to close DCs is more critical**, while the option to open DCs is less impactful for the success of the collaboration.

Assessing the Environmental Benefits of Horizontal Cooperation using a Location-Inventory Model

Thomas Hacardiaux, Jean-Sébastien Tancrez

Hacardiaux, T., Tancrez, J. S. (2020). Assessing the environmental benefits of horizontal cooperation using a location-inventory model. **Central European Journal of Operations Research**, 28(4), 1363-1387.

Objectives' priority

The assessment of the possible CO_2 emissions reductions as an additional **motivation to cooperate** horizontally.

When deciding on the **supply network design**, the focus is given on **cost reduction**.

As our model provides the traveled distances and the loading rate of the vehicles (shipment sizes), it allows to apply the **CO_2 emissions computation** a posteriori (Pan et al., 2013).

$$\epsilon_{dr}^v = \epsilon^{ve} \frac{\Lambda_r}{Q_{dr}} + (\epsilon^{vf} - \epsilon^{ve}) \frac{\Lambda_r}{C_{dr}}$$

➡ If the carried quantity doubles, the emissions **less than double**.

Conclusion - Managerial Insights (1/2)

- ▀ We observe an **average CO₂ emissions reduction of 16.3%**, showing the significant environmental benefits that horizontal cooperation can bring.
- ▀ However, **the reductions vary significantly**, ranging from 0.2% and 35.9%.
- ▀ The reduction in CO₂ emissions comes from **two main factors**:
 - ① Sharing their distribution centers reduces the average **distance to the retailers by 10.5%**.
 - ② Sharing vehicles improves the average **vehicle loading rate by 11%**, and leads to a reduction in the total **number of trips per period by 12.5%** on average.

Conclusion - Managerial Insights (2/2)

<i>Comparison</i>	<i>F_d</i>		<i>Cap%</i>	<i>K_d</i>	<i>H_dⁱ = H_rⁱ</i>	<i>Width</i>	<i>CV</i>	<i>#Partners</i>
	1000 4000	10 100	250 1000	0.25 1	500 1000	0.4 1	2 4	
CO2 Emissions	-8.2%	+3.9%	-5.5%	+3.6%	+3.9%	+0.7%	+14.5%	
Logistic Cost	+3.5%	+7.1%	-3.1%	-3.1%	+0.5%	-1.2%	+13.4%	

➡ The horizontal cooperation is **more environmentally profitable if**:

- ① Low facility opening costs;
- ② Unsuited vehicle capacity;
- ③ Low order costs;
- ④ Expensive products;
- ⑤ Vast market;
- ⑥ High demand variability;
- ⑦ High number of partners (28.7% and 33.8% with 3 and 4 partners).

Balancing partner preferences for logistics costs and carbon footprint in a horizontal cooperation

Thomas Hacardiaux, Christof Defryn, Jean-Sébastien Tancrez, Lotte Verdonck

- Hacardiaux, T., Defryn, C., Tancrez, J-S., Verdonck, L. (2020). Balancing partner preferences for logistics costs and carbon footprint in a horizontal cooperation. Maastricht University, Graduate School of Business and Economics. GSBE Research Memoranda, No. 002.
- Under revision for **OR Spectrum Journal**

Individuality of partners

⇒ **Observation:** companies with different (potentially conflicting) preferences could **improve their individual outcome by diverging** from the joint solution.

⇒ **Contributions:**

- 1 First, we develop a multi-objective framework accounting for the **individuality of partners** in terms of their **costs-emissions** preferences and their **influence** weights.
- 2 Second, we propose new approaches for **solving our multi-objective multi-partner model**; two approaches resulting in **Pareto fronts** and three approaches defining **unique solutions**.

⇒ **Consequently**, all stakeholders should be more likely to **accept the solution**, and the **long-term viability** of the collaboration is improved.

Location-Inventory Model

A multi-objective and multi-partner model with $2n_I$ objectives.

$$\begin{aligned} \min \quad & \frac{\Lambda^i}{\Lambda} \sum_d F y_d + \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d T D_{dr} \frac{\Lambda_r}{Q_{dr}} x_{dr} + \sum_{d,r} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} \\ & + \sum_d \sqrt{2 K_d^i h_d^i} v_{1d}^i + \sum_{d,r} H_r^i z_{\alpha}^i \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_d h_d^i z_{\alpha}^i \sqrt{L T_d^i} v_{2d}^i \quad \forall i \end{aligned}$$

$$\min \quad \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d \left[\epsilon^e \frac{\Lambda_r}{Q_{dr}} + (\epsilon^f - \epsilon^e) \frac{\Lambda_r}{C} \right] D_{dr} x_{dr} \quad \forall i$$

$$\text{s.t.} \quad \sum_r \lambda_r^i (x_{dr})^2 \leq (v_{1d}^i)^2 \quad \forall d, i$$

$$\sum_r (\sigma_r^i)^2 (x_{dr})^2 \leq (v_{2d}^i)^2 \quad \forall d, i$$

$$\sum_d x_{dr} = 1 \quad \forall r$$

$$x_{dr} \leq y_d \quad \forall d, r$$

$$v_{1d}^i, v_{2d}^i \geq 0 \quad \forall d, i$$

$$x_{dr}, y_d \in \{0, 1\} \quad \forall d, r$$

Two approaches resulting in Pareto fronts

$$\min \quad \frac{\Lambda^i}{\Lambda} \sum_d F y_d + \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d T D_{dr} \frac{\Lambda_r}{Q_{dr}} x_{dr} + \sum_{d,r} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} + \sum_d \sqrt{2 K_d^i h_d^i} v_{1d}^i$$

$$+ \sum_{d,r} H_r^i z_\alpha^i \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_d h_d^i z_\alpha^i \sqrt{L T_d^i} v_{2d}^i \quad \forall i$$

$$\min \quad \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d \left[\epsilon^e \frac{\Lambda_r}{Q_{dr}} + (\epsilon^f - \epsilon^e) \frac{\Lambda_r}{C} \right] D_{dr} x_{dr} \quad \forall i$$

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$$\min \quad \frac{\Lambda_r^i}{\Lambda} \sum_d F y_d + \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d T D_{dr} \frac{\Lambda_r}{Q_{dr}} x_{dr} + \sum_{d,r} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} + \sum_d \sqrt{2 K_d^i h_d^i} v_{1d}^i$$

$$+ \sum_{d,r} H_r^i z_\alpha^i \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_d h_d^i z_\alpha^i \sqrt{L T_d^i} v_{2d}^i \quad \forall i$$

$$\min \quad \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d \left[\epsilon^e \frac{\Lambda_r}{Q_{dr}} + (\epsilon^f - \epsilon^e) \frac{\Lambda_r}{C} \right] D_{dr} x_{dr} \quad \forall i$$

➡ Approach 1: Articulation at the coalition level

$$\min \quad \sum_d F y_d + \sum_{d,r} T D_{dr} \frac{\Lambda_r}{Q_{dr}} x_{dr} + \sum_{d,r,i} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} + \sum_{d,i} \sqrt{2 K_d^i h_d^i} v_{1d}^i$$

$$+ \sum_{d,r,i} H_r^i z_\alpha^i \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_{d,i} h_d^i z_\alpha^i \sqrt{L T_d^i} v_{2d}^i$$

$$\min \quad \sum_{d,r} \left[\epsilon^e \frac{\Lambda_r}{Q_{dr}} + (\epsilon^f - \epsilon^e) \frac{\Lambda_r}{C} \right] D_{dr} x_{dr}$$

Two approaches resulting in Pareto fronts

$$\min \quad \frac{\Lambda^i}{\Lambda} \sum_d F y_d + \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d T D_{dr} \frac{\Lambda_r}{Q_{dr}} x_{dr} + \sum_{d,r} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} + \sum_d \sqrt{2 K_d^i h_d^i} v_{1d}^i$$

$$+ \sum_{d,r} H_r^i z_{\alpha}^i \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_d h_d^i z_{\alpha}^i \sqrt{L T_d^i} v_{2d}^i \quad \forall i$$

$$\min \quad \sum_r \frac{\lambda_r^i}{\Lambda_r} \sum_d \left[\epsilon^e \frac{\Lambda_r}{Q_{dr}} + (\epsilon^f - \epsilon^e) \frac{\Lambda_r}{C} \right] D_{dr} x_{dr} \quad \forall i$$

➡ Approach 2: Articulation at the partner level

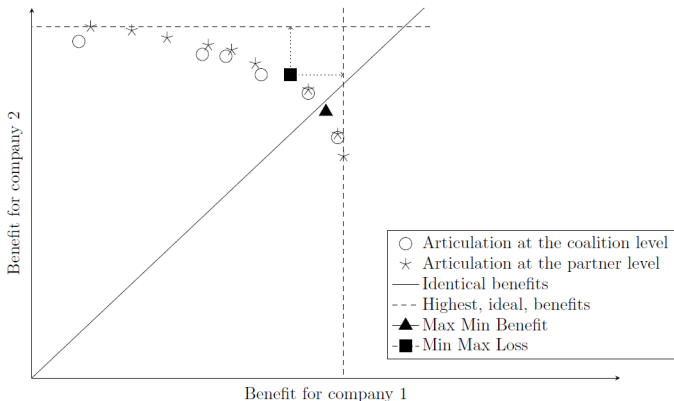
$$\min \quad \frac{\Lambda^i}{\Lambda} \sum_d F y_d + \sum_{d,r} T D_{dr} \frac{\lambda_r^i}{Q_{dr}} x_{dr} + \sum_{d,r} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} x_{dr} + \sum_d \sqrt{2 K_d^i h_d^i} v_{1d}^i$$

$$+ \sum_{d,r} H_r^i z_{\alpha}^i \sigma_r^i \sqrt{L T_{dr}} x_{dr} + \sum_d h_d^i z_{\alpha}^i \sqrt{L T_d^i} v_{2d}^i + \beta^i \sum_{d,r} \left[\epsilon^e \frac{\lambda_r^i}{Q_{dr}} + (\epsilon^f - \epsilon^e) \frac{\lambda_r^i}{C} \right] D_{dr} x_{dr}$$

$$\quad \forall i$$

Partners benefits

- ➡ We obtain two **sets of Pareto-optimal solutions** that can support the negotiation and decision-making process.
- ➡ The Pareto fronts **balance either the logistics costs and CO₂ emissions** or compromise **the partners' augmented costs**.



Identifying unique solutions

Three approaches to highlight a solution

1) Preference articulation at coalition level

Transform the individual preferences (β^i) into a collaborative weight (β) based on the volumes or the augmented costs of partners.

2) Preference articulation at individual level

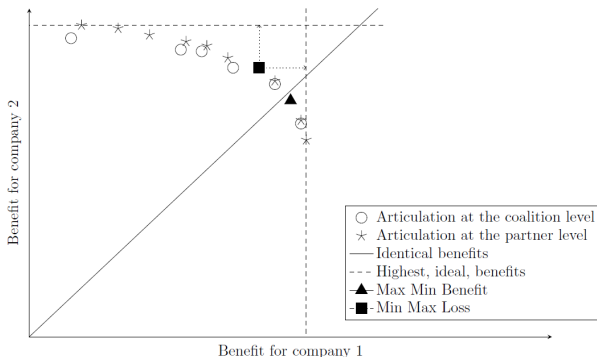
Generate partner's influence weight γ^i which characterize the influence of the companies on the final cooperative solution. To define them, we rely again on demand volumes or the stand-alone augmented costs.

Identifying unique solutions

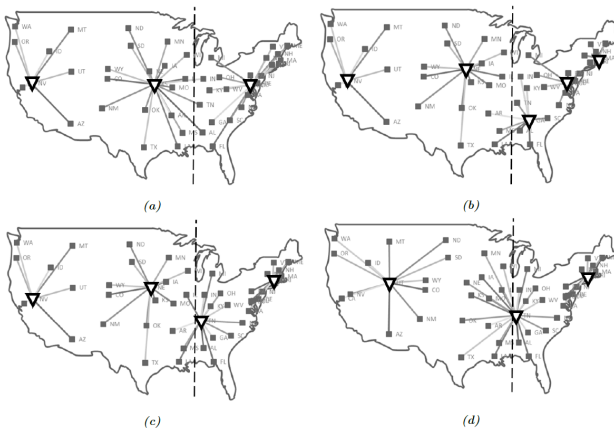
3) Partners benefits approach

Look at the benefits that cooperation generates for the partners individually.

- 1 Maximizing the minimal partner benefit.
- 2 Minimizing the maximal partner loss



Different geographical demand distribution



➡ When geographical spread and individual preferences differ, applying **approaches that conserve individual preferences** allows to design a network with **different priorities** in the regions.

Conclusion

- ➡ Current research considers horizontal logistics collaboration as a **single-objective minimization** of transportation costs, assuming partners agree on a **unique collaborative goal**.
- ➡ We propose a **multi-objective** and **multi-partner** model including the **individual costs-emissions preferences** and the partners' influence weight in the collaboration.
- ➡ Collaboration **remains beneficial** for both partners in all cases.
- ➡ However, preference weight combinations **impact the individual benefits levels** of the partners.
- ➡ When partners' preferences are different, each company **benefits more from** a reduction of **its non-priority objective**.

General Conclusion

⇒ We assess the **benefits of horizontal cooperation**.

- ① Minimising the costs.
- ② Minimising the costs then the CO2 emissions.
- ③ Minimising both objectives at the same time.

⇒ We provide **valuable managerial insights** for companies that want to cooperate depending on partners' and markets' characteristics.

⇒ We incorporate individual objectives of partners in the model to guaranty **the sustainability** of the collaboration.

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