Evaluating Horizontal Cooperation in Supply Chains

Thomas Hacardiaux, Jean-Sébastien Tancrez

Louvain School of Management, CORE, UCLouvain

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Horizontal Cooperation

"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)*

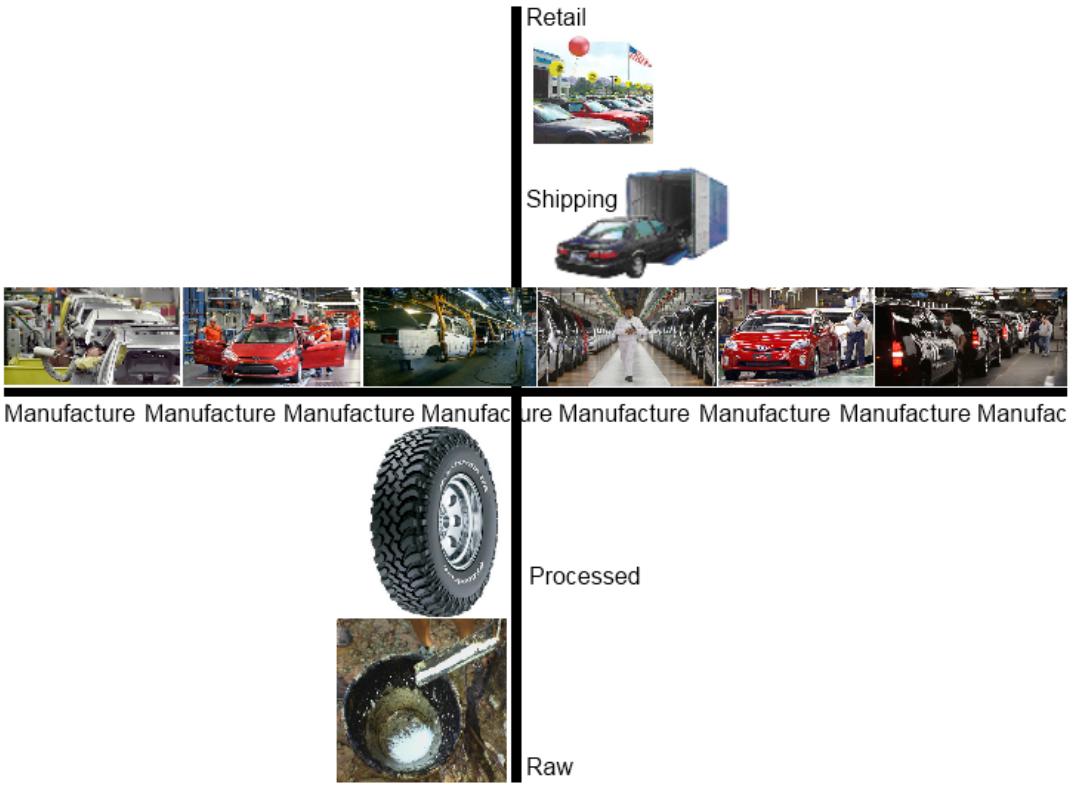


Figure: http://amh2020-0005.tumblr.com

Literature

Savings related to the cooperation exist in any cases but go **from a reduction of 5% to about 30%.**

1. Bahrami (2002): reduction of 9.8% of costs.
2. Frisk et al. (2010): reduction between 5 and 15% with a collaborative planning.
3. Krajewska et al (2008): reduction of the transportation cost of 12.46%.
4. Cruijssen et al. (2007): reduction of 30.7% using a joint route planning.

Location-Inventory Model

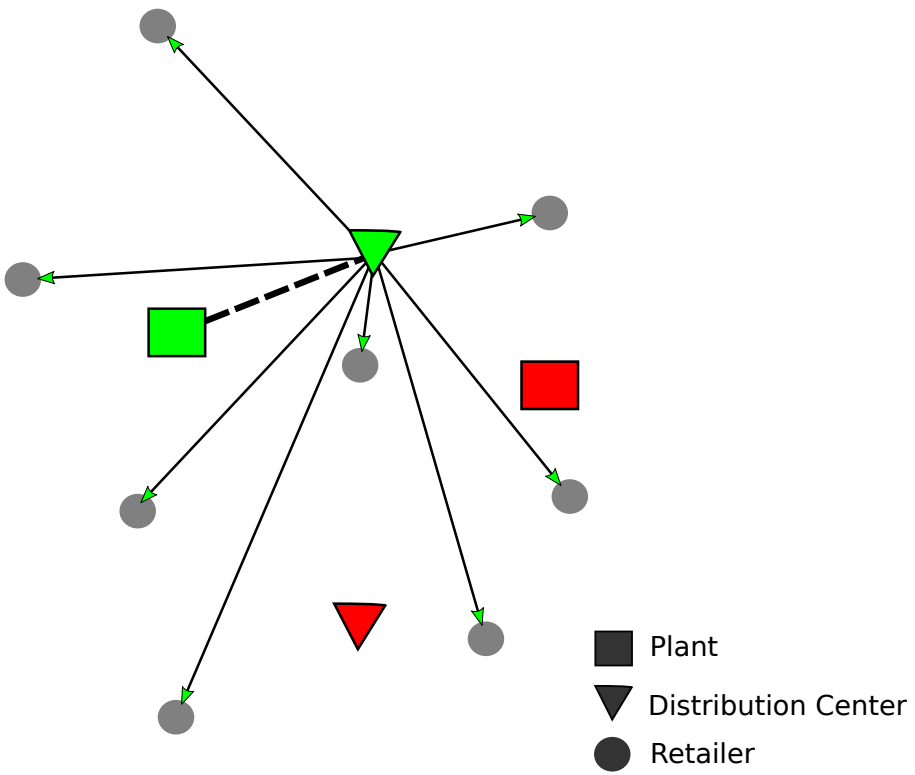
We use a **location-inventory model** to determine:

1. The number and the locations of the distribution centers.
2. The delivery network.
3. The inventory decisions.

Transportation costs are **proportional to the number of vehicles** required instead of product flow.

Benefit 1: Reduction of the Distances

1. Two companies with their own independent plants and **different products**.
2. Each company receives orders from retailers for its product.
3. The products of each companies **can be stored and delivered together**.



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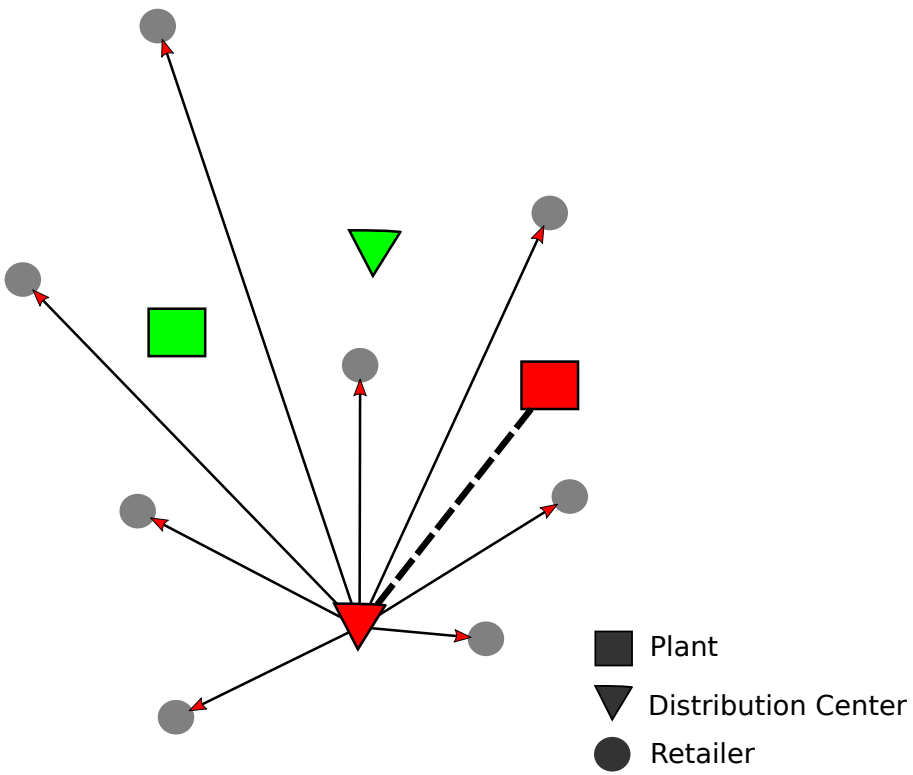

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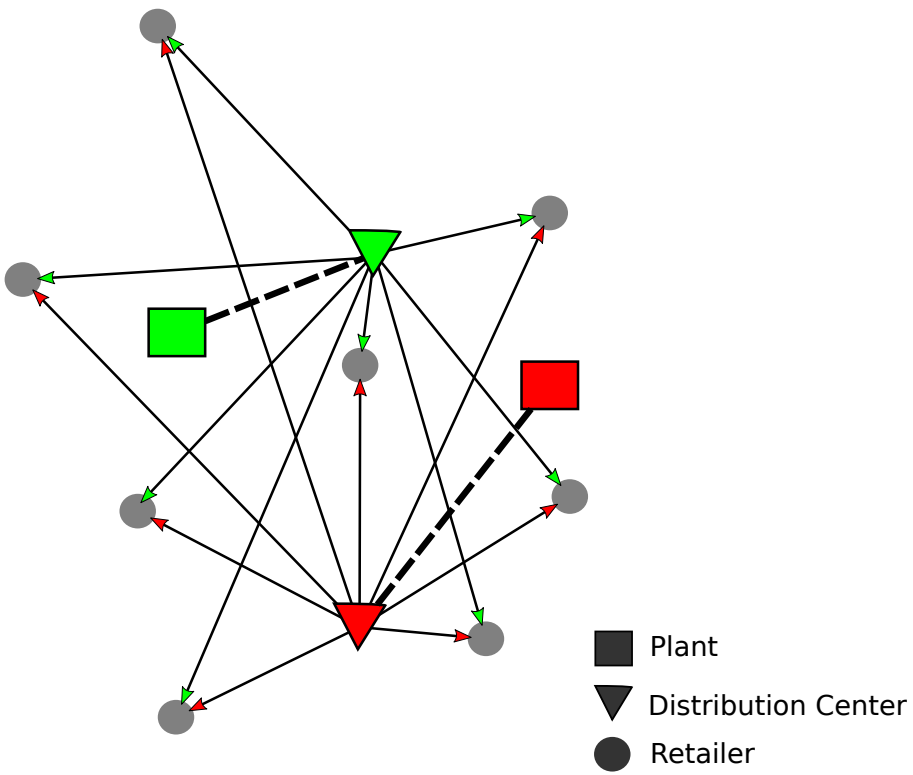

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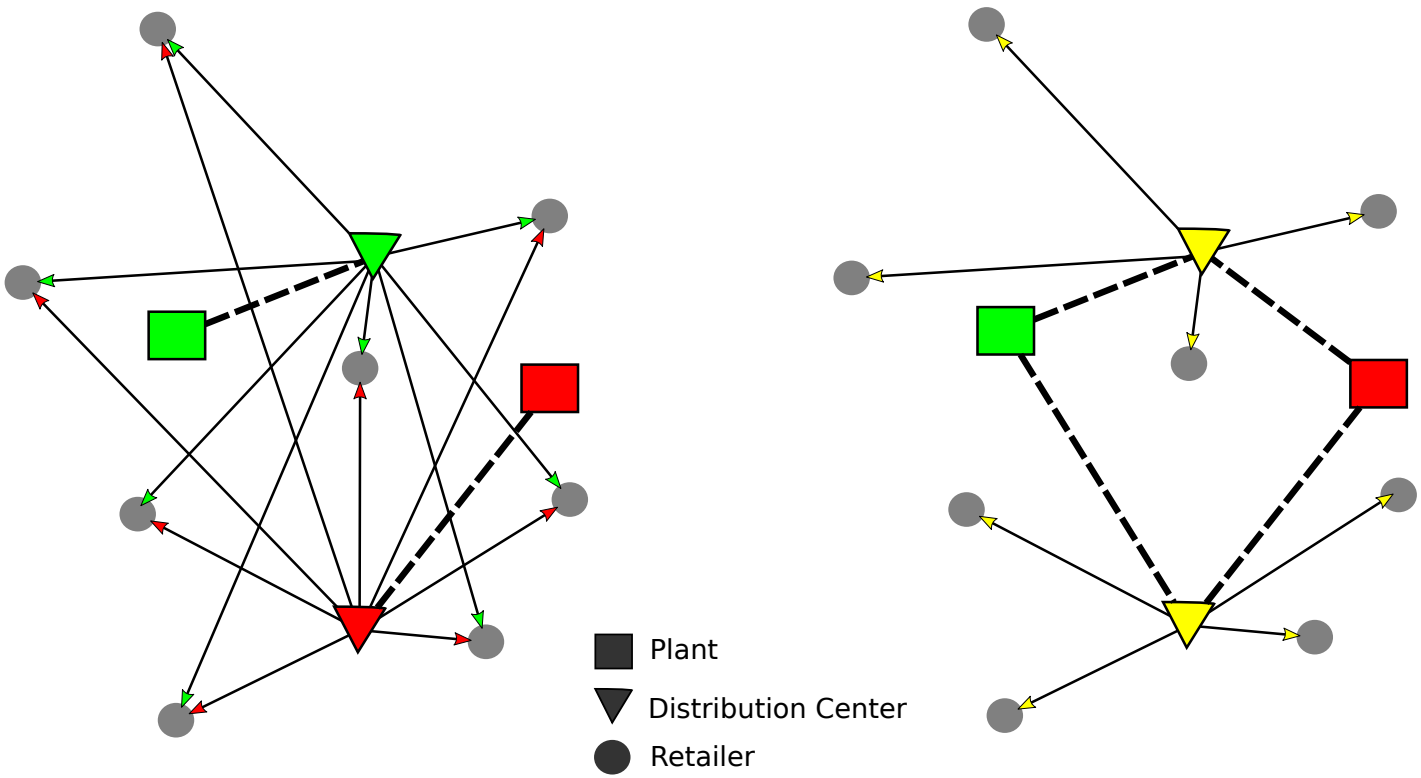
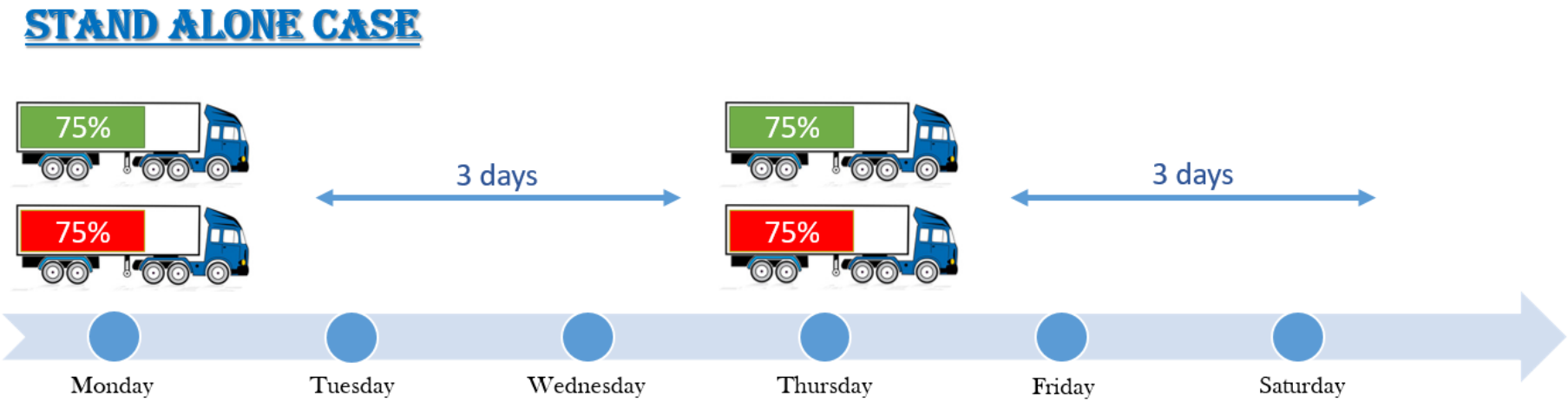


Benefit 2: Better Loading Rate



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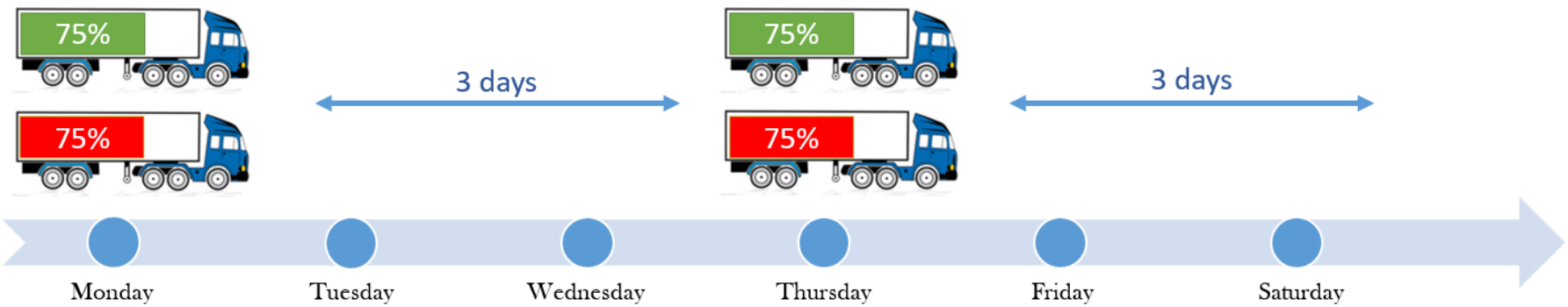
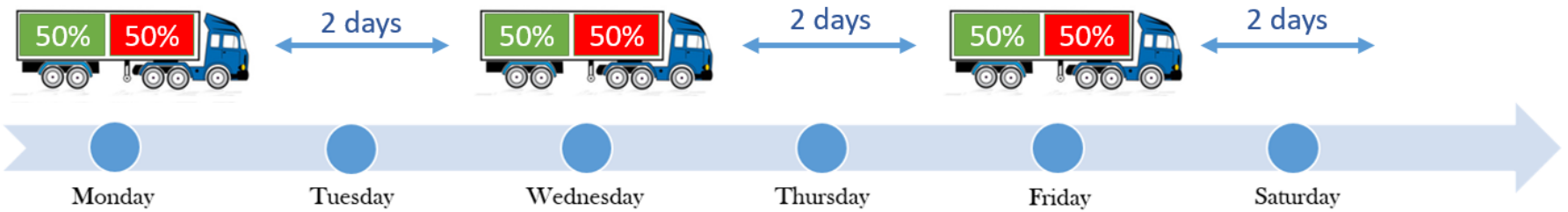
STAND ALONE CASE



COOPERATIVE CASE



1. Higher delivery frequency.
2. Higher loading rate.
3. Lower number of vehicles/deliveries.

Location Inventory Model

We aim at **minimizing the total cost** composed of transportation, cycle inventory, ordering, facility opening and safety stock costs.

$$
\begin{aligned}
Min \quad & \sum_{d,r} O_{dr} \frac{\Lambda_r}{Q_{dr}} y_{dr} + \sum_{d,r,i} H_r^i \frac{Q_{dr}}{2} \frac{\lambda_r^i}{\Lambda_r} y_{dr} + \sum_{d,i} \sqrt{2\, K_d^i\, H_d^i}\, v_{1d}^i \\
& + \sum_{d} F_d\, y_d + \sum_{d,i} H_d^i\, z_\alpha^i \sqrt{LT_d^i}\, v_{2d}^i + \sum_{d,r,i} H_r^i\, z_\alpha^i\, \sigma_r^i \sqrt{LT_{dr}}\, y_{dr} \\
s.t. \quad & \sum_r \lambda_r^i \left(y_{dr}\right)^2 \le \left(v_{1d}^i\right)^2 \qquad \forall d, i \\
& \sum_r (\sigma_r^i)^2 \left(y_{dr}\right)^2 \le \left(v_{2d}^i\right)^2 \qquad \forall d, i \\
& \sum_d y_{dr} = 1 \qquad \forall r \\
& y_{dr} \le y_d \qquad \forall d, r \\
& v_{1d}^i, v_{2d}^i \ge 0 \qquad \forall d, i \\
& y_{dr}, y_d \in \{0, 1\} \qquad \forall d, r
\end{aligned}
$$

Experiments

Our research proceeds in **three steps**.

1. Designing the supply chain networks of the companies when they are independent.
2. Designing the supply chain networks when they collaborate.
3. Comparing results between the sum of the stand alone cases and the cooperation case.

We evaluate the coalition gain, also called the **synergy value**, using the formula by Cruijssen et al. (2007).

$$S(A,B) = \frac{c(A) + c(B) - c(A,B)}{c(A) + c(B)} * 100$$

Parameter Combinations

Network Parameters	
$n_r = n_d$	60
Width	(500, 1000) km
Capacity Percentages	(10, 20, 30, 40, 50, 60, 70, 80, 90, 100)
Demand Parameters	
Λ_r	$\in$ [50, 250] items/week
CV	(0.4, 0.7, 1)
α	97,5%
z_α^i	1,96
Cost Parameters	
F_d	(1000, 2000, 4000) €/week
K_d^i	(250, 500, 1000) €/order
$H_d^i = H_r^i$	(0.25, 0.50, 1) €/item·week

A total of **24,300 experiments** is performed in our analysis.

1. 1620 parameter combinations ($2 \cdot 10 \cdot 3 \cdot 3 \cdot 3 \cdot 3$).
2. Five maps are generated resulting in 8100 instances.
3. We run the model three times: when companies are independents (2 cases) and when they decide to cooperate.
4. Average optimality gap 0.25% - limited to 1800 seconds.

Synergy Value

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% 5.20|3.23 0.94|0.97	14.86% 6.23|4.27 0.95|0.98	15.87% 7.37|4.87 0.96|0.99	18.95% 5.17|3.37 0.94|0.97	16.80% 6.50|4.10 0.95|0.98	14.73% 7.77|5.03 0.96|0.99	16.82% 6.37|4.14 0.95|0.98
	40%	21.91% 3.77|2.53 0.86|0.92	20.85% 4.87|3.00 0.85|0.93	19.09% 5.83|3.60 0.86|0.94	21.19% 3.37|2.50 0.86|0.92	19.76% 4.93|3.13 0.85|0.93	17.50% 6.03|3.77 0.86|0.95	20.05% 4.80|3.09 0.86|0.93
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1000	10%	19.70% 5.20|3.23 0.94|0.97	14.86% 6.23|4.27 0.95|0.98	15.87% 7.37|4.87 0.96|0.99	18.95% 5.17|3.37 0.94|0.97	16.80% 6.50|4.10 0.95|0.98	14.73% 7.77|5.03 0.96|0.99	16.82% 6.37|4.14 0.95|0.98
	40%	21.91% 3.77|2.53 0.86|0.92	20.85% 4.87|3.00 0.85|0.93	19.09% 5.83|3.60 0.86|0.94	21.19% 3.37|2.50 0.86|0.92	19.76% 4.93|3.13 0.85|0.93	17.50% 6.03|3.77 0.86|0.95	20.05% 4.80|3.09 0.86|0.93
	70%	23.60% 3.73|1.93 0.75|0.89	22.61% 4.23|2.50 0.74|0.88	21.11% 5.20|3.00 0.75|0.89	22.68% 3.13|1.97 0.75|0.87	21.47% 4.30|2.63 0.74|0.88	19.37% 5.60|3.10 0.74|0.89	21.81% 4.36|2.52 0.75|0.88
	100%	25.55% 3.53|1.50 0.54|0.72	24.46% 4.07|1.97 0.51|0.71	23.07% 4.80|2.27 0.50|0.70	24.34% 2.90|1.60 0.53|0.70	23.03% 4.10|2.17 0.50|0.68	21.00% 5.23|2.70 0.50|0.68	23.57% 4.11|2.03 0.51|0.70
4000	10%	20.54% 2.13|1.03 0.97|0.99	18.82% 2.00|1.57 0.97|0.98	19.11% 2.23|2.33 0.97|0.98	19.88% 2.03|1.10 0.97|0.98	18.13% 2.00|1.67 0.97|0.98	18.33% 2.43|2.37 0.96|0.98	19.14% 2.14|1.68 0.97|0.98
	40%	26.11% 2.20|1.07 0.88|0.96	23.70% 2.17|1.13 0.89|0.97	22.00% 2.00|1.33 0.90|0.95	25.18% 2.10|1.00 0.88|0.96	22.47% 2.03|1.10 0.89|0.97	20.52% 2.07|1.43 0.89|0.95	23.33% 2.09|1.18 0.89|0.96
	70%	28.85% 2.20|1.00 0.78|0.93	26.62% 2.33|1.00 0.78|0.93	24.62% 2.07|1.13 0.79|0.92	27.80% 2.40|1.00 0.78|0.93	25.17% 2.20|1.00 0.78|0.93	22.78% 2.00|1.20 0.79|0.91	25.97% 2.20|1.06 0.78|0.92
	100%	30.62% 2.40|1.20 0.58|0.79	28.63% 2.33|1.00 0.55|0.77	26.70% 2.10|1.10 0.56|0.76	29.57% 2.40|1.33 0.56|0.78	27.06% 2.33|1.07 0.55|0.77	24.60% 2.03|1.07 0.56|0.75	27.86% 2.27|1.13 0.56|0.77
Average		24.61% 3.15|1.69 0.79|0.89	22.57 3.53|2.05 0.78|0.89	21.45% 3.95|2.45 0.78|0.89	23.70% 2.94|1.73 0.78|0.89	21.74% 3.55|2.11 0.78|0.89	19.85% 4.15|2.58 0.78|0.88	22.32% 3.55|2.10 0.78|0.89

Synergy Value

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% 5.20|3.23 0.94|0.97	14.86% 6.23|4.27 0.95|0.98	15.87% 7.37|4.87 0.96|0.99	18.95% 5.17|3.37 0.94|0.97	16.80% 6.50|4.10 0.95|0.98	**14.73%** 7.77|5.03 0.96|0.99	16.82% 6.37|4.14 0.95|0.98
	40%	21.91% 3.77|2.53 0.86|0.92	20.85% 4.87|3.00 0.85|0.93	19.09% 5.83|3.60 0.86|0.94	21.19% 3.37|2.50 0.86|0.92	19.76% 4.93|3.13 0.85|0.93	17.50% 6.03|3.77 0.86|0.95	20.05% 4.80|3.09 0.86|0.93
	70%	23.60% 3.73|1.93 0.75|0.89	22.61% 4.23|2.50 0.74|0.88	21.11% 5.20|3.00 0.75|0.89	22.68% 3.13|1.97 0.75|0.87	21.47% 4.30|2.63 0.74|0.88	19.37% 5.60|3.10 0.74|0.89	21.81% 4.36|2.52 0.75|0.88
	100%	25.55% 3.53|1.50 0.54|0.72	24.46% 4.07|1.97 0.51|0.71	23.07% 4.80|2.27 0.50|0.70	24.34% 2.90|1.60 0.53|0.70	23.03% 4.10|2.17 0.50|0.68	21.00% 5.23|2.70 0.50|0.68	23.57% 4.11|2.03 0.51|0.70
4000	10%	20.54% 2.13|1.03 0.97|0.99	18.82% 2.00|1.57 0.97|0.98	19.11% 2.23|2.33 0.97|0.98	19.88% 2.03|1.10 0.97|0.98	18.13% 2.00|1.67 0.97|0.98	18.33% 2.43|2.37 0.96|0.98	19.14% 2.14|1.68 0.97|0.98
	40%	26.11% 2.20|1.07 0.88|0.96	23.70% 2.17|1.13 0.89|0.97	22.00% 2.00|1.33 0.90|0.95	25.18% 2.10|1.00 0.88|0.96	22.47% 2.03|1.10 0.89|0.97	20.52% 2.07|1.43 0.89|0.95	23.33% 2.09|1.18 0.89|0.96
	70%	28.85% 2.20|1.00 0.78|0.93	26.62% 2.33|1.00 0.78|0.93	24.62% 2.07|1.13 0.79|0.92	27.80% 2.40|1.00 0.78|0.93	25.17% 2.20|1.00 0.78|0.93	22.78% 2.00|1.20 0.79|0.91	25.97% 2.20|1.06 0.78|0.92
	100%	**30.62%** 2.40|1.20 0.58|0.79	28.63% 2.33|1.00 0.55|0.77	26.70% 2.10|1.10 0.56|0.76	29.57% 2.40|1.33 0.56|0.78	27.06% 2.33|1.07 0.55|0.77	24.60% 2.03|1.07 0.56|0.75	27.86% 2.27|1.13 0.56|0.77
Average		24.61% 3.15|1.69 0.79|0.89	22.57 3.53|2.05 0.78|0.89	21.45% 3.95|2.45 0.78|0.89	23.70% 2.94|1.73 0.78|0.89	21.74% 3.55|2.11 0.78|0.89	19.85% 4.15|2.58 0.78|0.88	**22.32%** 3.55|2.10 0.78|0.89

Managerial Insights

The synergy value varies between around **15% and 30%**.

We observe that companies have **strong incentives** to cooperate **when**:

1. Companies have large, not fully loaded, vehicles (+7.1%).
2. Opening costs are high (+3.5%).
3. Companies transport small cheap products (-3.1%).
4. The demand variability is low (-1.2%).

Impact of the Number of Partners

The addition of new partners allows an increase of the average synergy value from **22.3%** with 2 partners to **31.2%** and **36%** with 3 and 4 partners respectively.

1. It reduces inventory by delivering products **more frequently** (delivered 3.4 times more often).
2. The vehicles are **load more efficiently** (from 78% to 95%).
3. More DCs are opened to be **closer to retailers**.

		F_d			$Cap\%$				$H_d^i = H_r^i$		$Coop.$	
	Avg	1000	2000	4000	10	40	70	100	0.25	1	DCs	LR
2 Partners	22.6%	21.0%	22.7%	24.0%	19.1%	21.7%	23.9%	25.6%	23.9%	21.2%	2.40	88.0%
	+8.6%	+7.9%	+8.9%	+9.2%	+7.7%	+8.1%	+8.8%	+10.1%	+9.2%	+8.2%	+0.46	+4.9%
3 Partners	31.2%	28.9%	31.6%	33.2%	26.8%	29.8%	32.7%	35.7%	33.1%	29.4%	2.86	92.9%
	+4.8%	+4.3%	+4.9%	+5.2%	+4.4%	+4.5%	+4.7%	+5.5%	+5.1%	+4.5%	+0.31	+1.9%
4 Partners	36.0%	33.2%	36.5%	38.4%	31.2%	34.3%	37.4%	41.2%	38.2%	33.9%	3.17	94.8%

Impact of the Use of Existing DCs

When companies prefer to **keep the same facilities locations** than in the stand alone cases and if:

1. They keep exactly **the same DCs**: synergy value of 14.4% (DCs not optimally located).
2. They accept to **close some DCs**: synergy value of 22% (39% of DCs are not used).
3. It reduces the **long-term commitment**.

		F_d			$Cap\%$				$H_d^i = H_r^i$		$Coop.$	
	Avg	1000	2000	4000	10	40	70	100	0.25	1	DCs	LR
New DCs	22.6%	21.0%	22.7%	24.0%	19.1%	21.7%	23.9%	25.6%	23.9%	21.2%	2.40	88.0%
	−0.6%	−0.4%	−0.6%	−0.6%	−1.2%	−0.6%	−0.3%	−0.1%	−0.5%	−0.5%	−0.45	+1.9%
Closing DCs	22.0%	20.6%	22.1%	23.4%	17.9%	21.1%	23.6%	25.5%	23.4%	20.6%	1.95	89.9%
	−7.6%	−6.7%	−7.0%	−9.2%	−8.1%	−7.6%	−7.5%	−7.4%	−8.5%	−6.7%	+1.75	−1.4%
Same DCs	14.4%	13.9%	15.1%	14.2%	9.8%	13.5%	16.1%	18.1%	14.9%	13.9%	3.70	88.5%

Conclusion

1. Our research shows **a strong variation** in the synergy value, around **15% and 30%**.
2. The horizontal cooperation is more profitable for companies with a **high facility opening cost**, a **large vehicle capacity** (or small size products) and a **low order cost**, carrying **cheap products** on a market with a **low demand variability**.
3. **More partners** improve the synergy value but the marginal gain decreases with each newcomer.
4. Keeping some of the **existing facilities** is a good option to mitigate the risks.

Future research:

1. Environmental benefit of horizontal cooperation (16.1% CO_2 emissions reductions).
2. Profit distribution.

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Main References

$$Q_{dr} = min\left(C_{dr}, \sqrt{\frac{2\,O_{dr}\,\Lambda_r}{\sum_i H_r^i \frac{\lambda_r^i}{\Lambda_r}}}\right) \qquad \forall d, r$$

The percentage can be translated as the theoretical percentage of retailers which are not constrain by the truck's capacity.

1. We begin by running the model without capacities for both companies. We obtain 120 optimal shipment sizes, Q_{dr}^i.
2. Values for retailers which are at the same location as opened DCs are removed and we rank the remaining values in ascending order.
3. We take the n-th value corresponding to the different percentages.
4. We restart the calculation when parameters change.