

# Coordination in Collaborative Logistics

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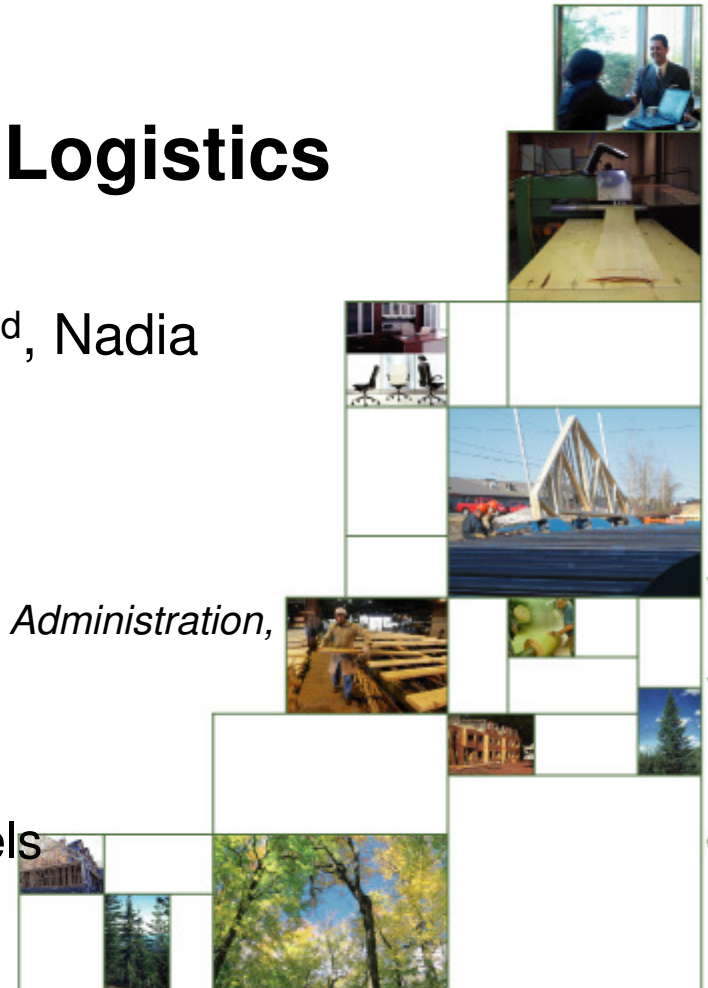
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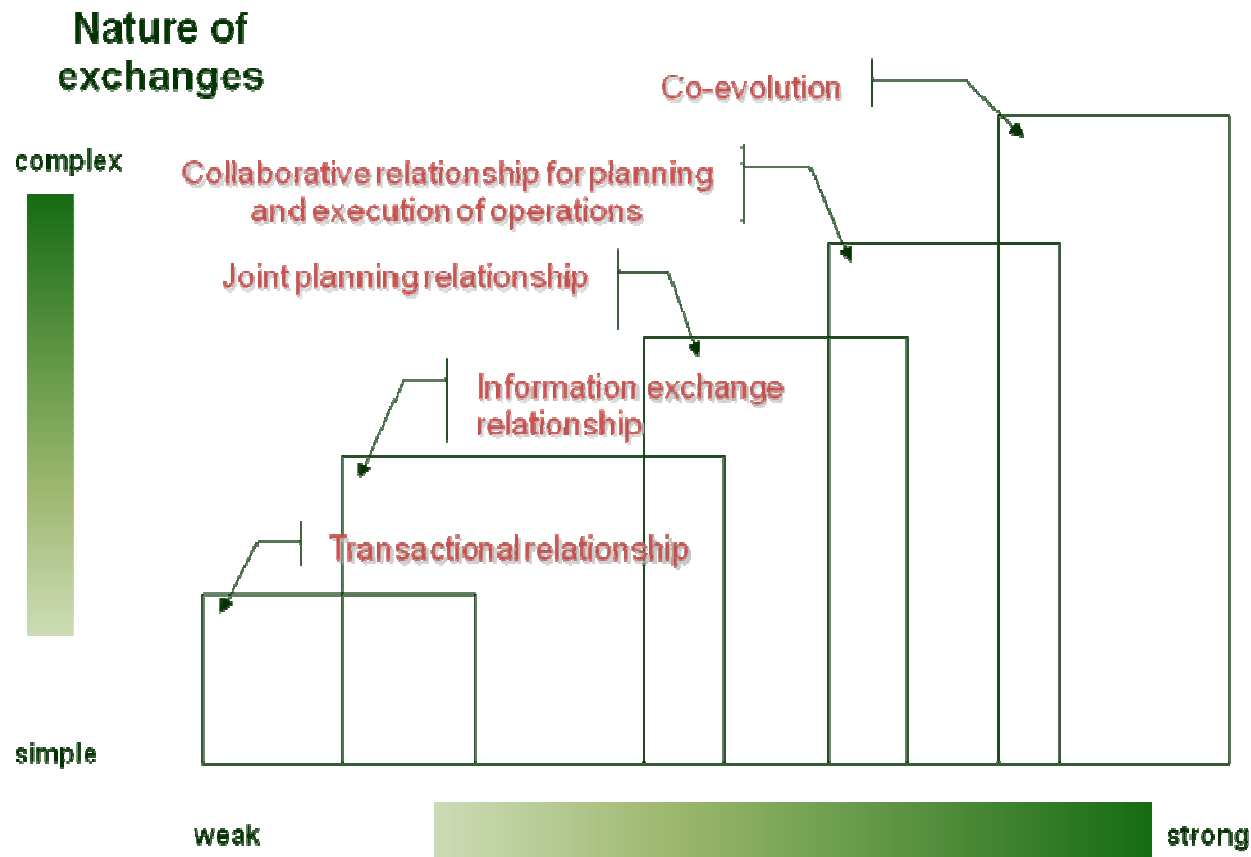
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# Collaboration in logistics

- **When two** (or more) **autonomous** and **self-interested business units form a coalition** and exchange or share resources (including information), with the goal of making decisions or undertaking activities that will **generate benefits that they cannot** (or only partially) **generate individually**
- **Logistics provides many opportunities for collaboration:**
  - High potential return
  - Low risk (operational level)
  - Different levels/dimensions of collaboration

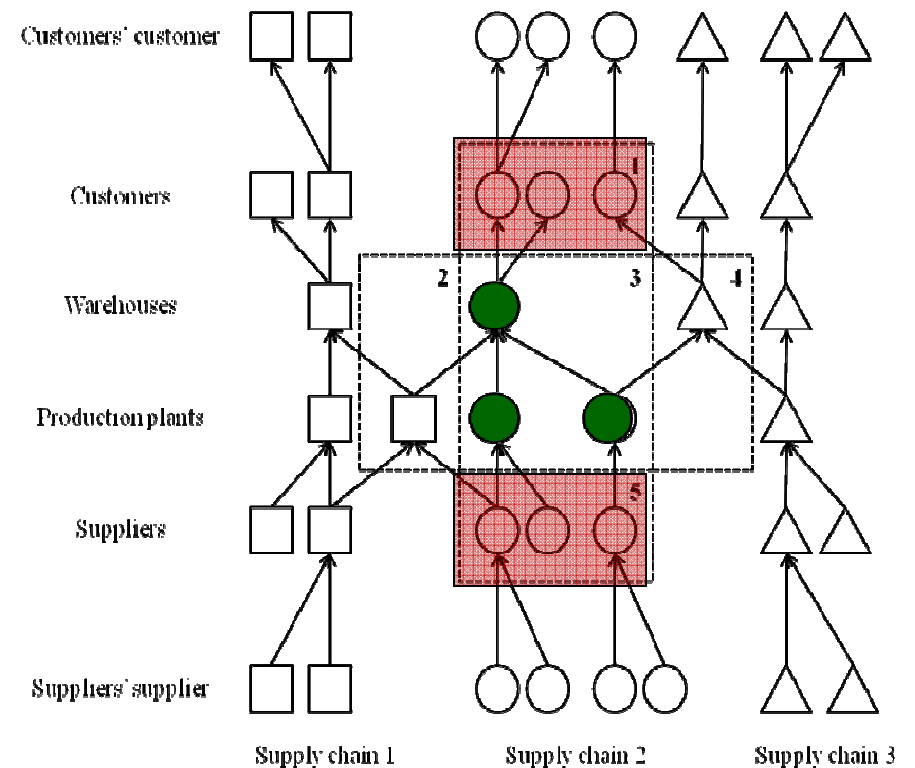
# Different levels of collaboration



From D'Amours *et al.* (2004)

# Different dimensions of collaboration

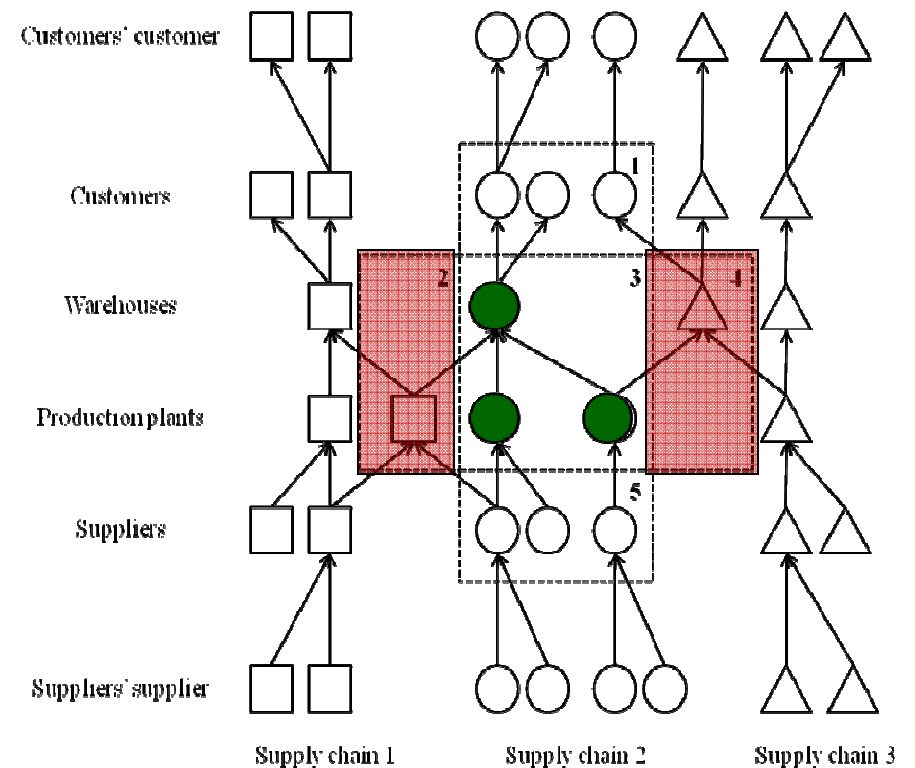
- Vertical: 1 and 5



Adapted from Barratt (2004)

## Different dimension of collaboration

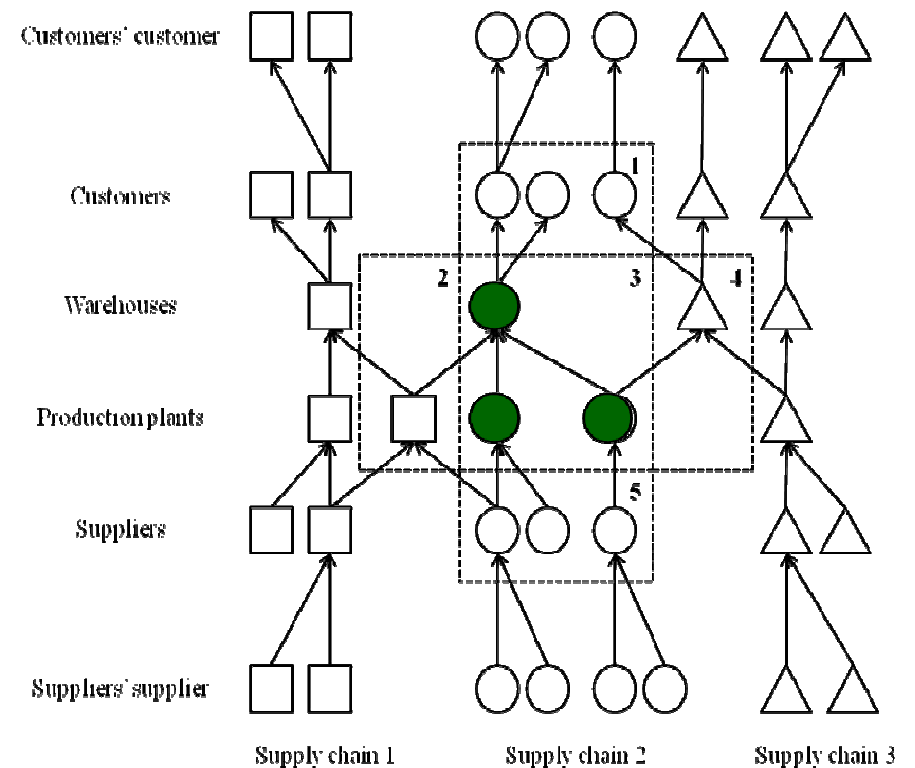
- Vertical: 1 and 5
- Horizontal: 2 and 4



Adapted from Barratt (2004)

## Different dimension of collaboration

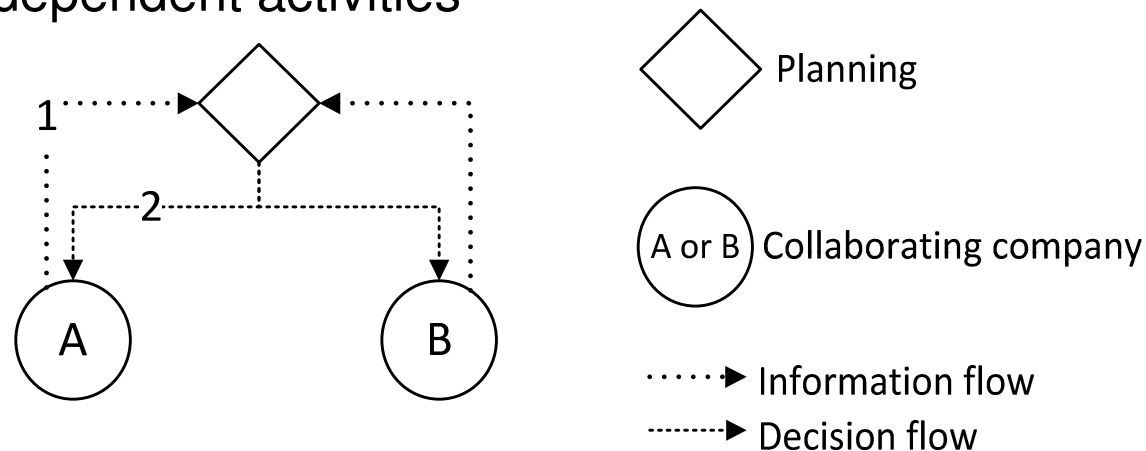
- Vertical: 1 and 5
- Horizontal: 2 and 4
- Lateral/diagonal/synergistic: 1 to 5



Adapted from Barratt (2004)

# Coordination mechanisms

- Classification scheme of **coordination mechanisms** of manufacturing activities in distributed manufacturing system (Frayret *et al.*, 2004):
  - One class: '**coordination by plan**' (from March and Simon, 1958)
    - **Establishment of predefined plans** to coordinate **a priori** interdependent activities



Adapted from Frayret *et al.* (2004)

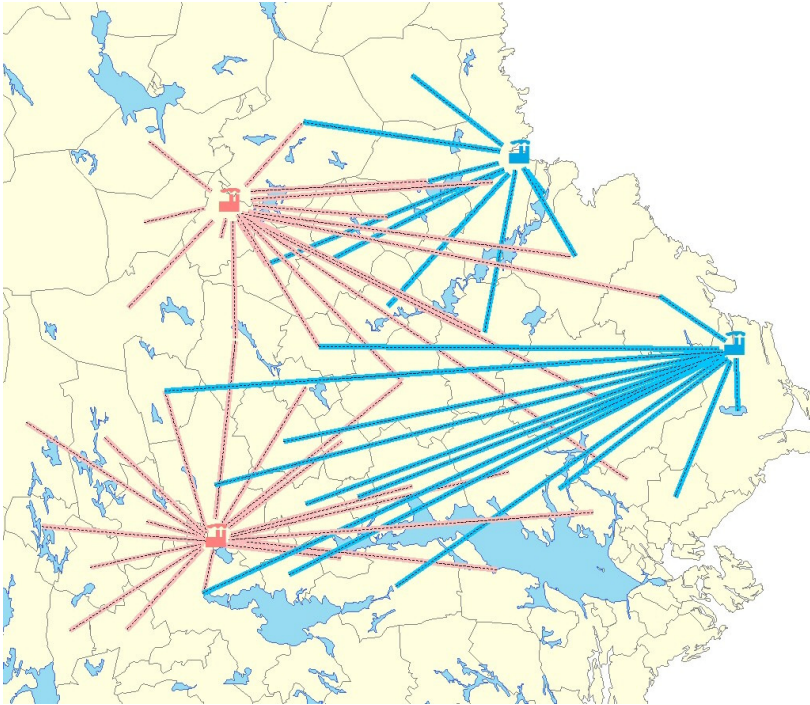
## Coordination mechanisms

- By addressing **financial issues within** these mechanisms, we **tailor** them to coordinate interdependent (vertical collaboration) or similar (horizontal collaboration) logistics activities
- Financial issues:
  - a) How to **compute** the potential financial benefit
  - b) How to **share** the potential financial benefit

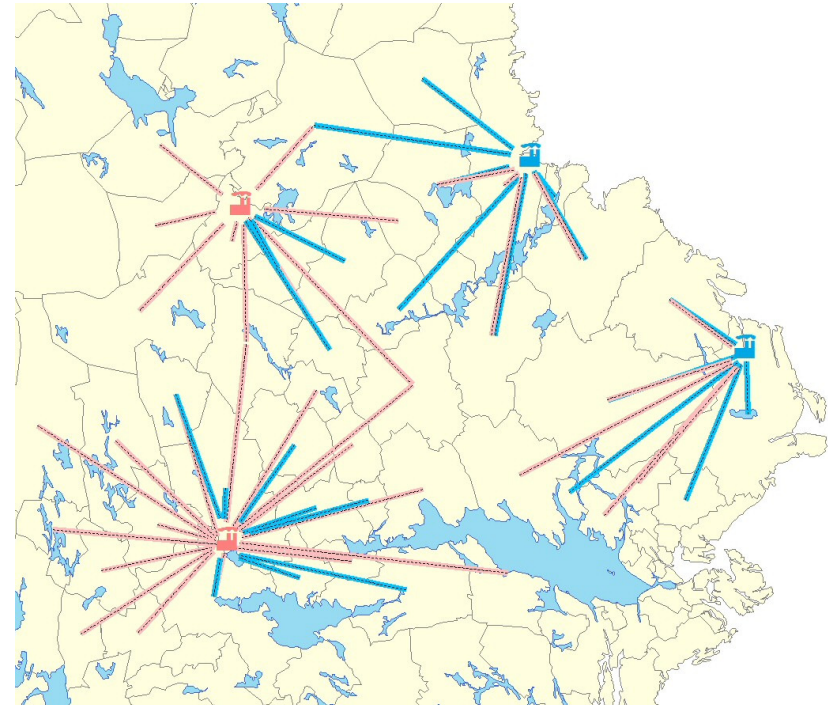
## How to compute?

- Optimization problems and Operations Research (OR) methods are used in several case studies involving collaboration in logistics
- Solution of **one** optimization problem
  - Predefined plan with a cost (Min objective) or a profit (Max objective)
- **Individual** and **common** optimization problems
  - Modifications could be required for common optimization problems

**Wood allocation (individual optimization problem)  
vs.  
Wood exchange (common optimization problem)**



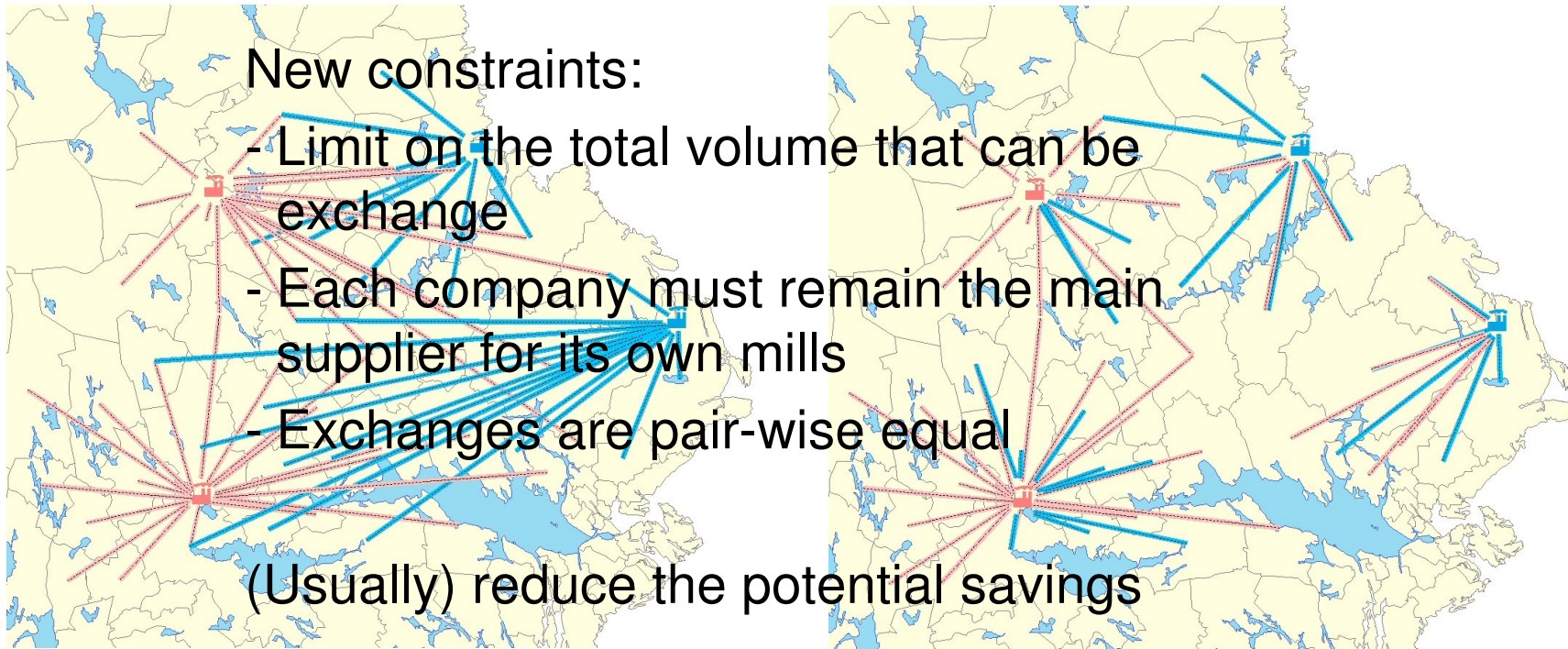
Individual plan



Collaborative plan

From Forsberg *et al.* (2005)

**Wood allocation (individual optimization problem)  
vs.  
Wood exchange (common optimization problem)**



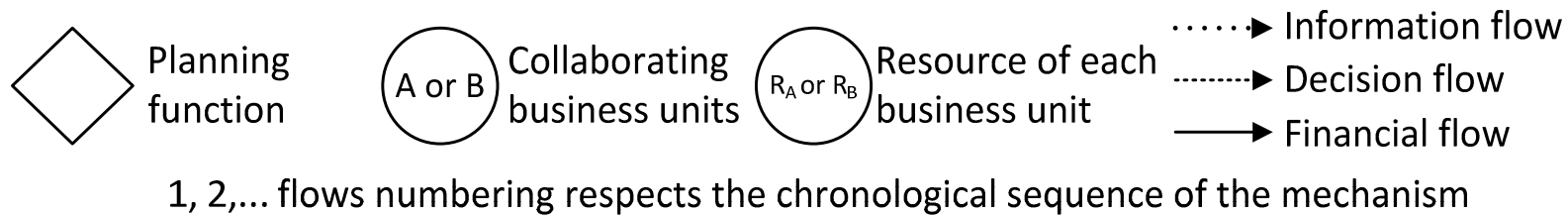
Individual plan

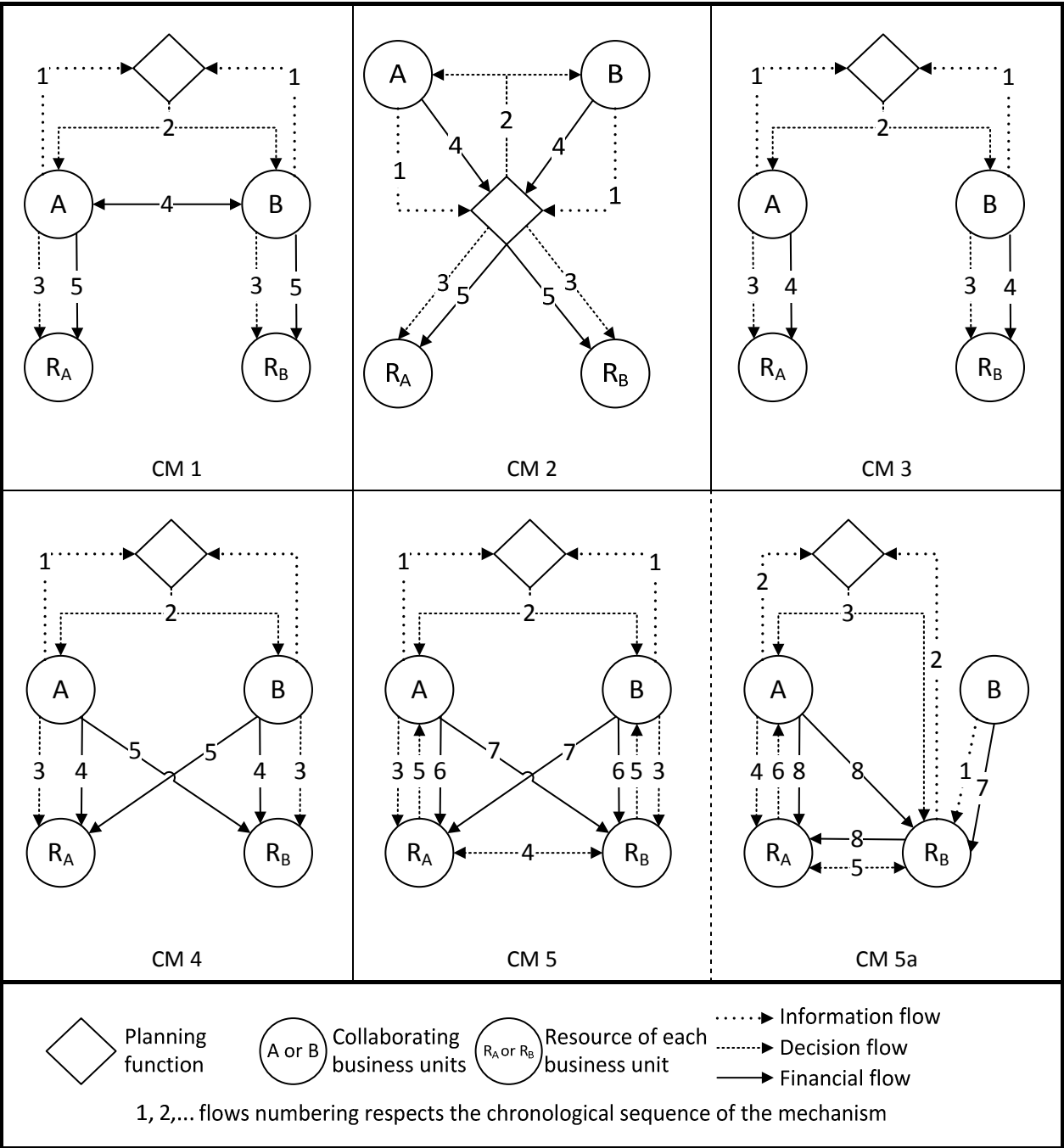
Collaborative plan

From Forsberg *et al.* (2005)

## How to share?

- Different sharing approaches are used in several case studies involving collaboration in logistics
  - Regroup in five generic coordination mechanisms

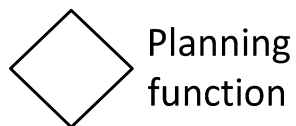
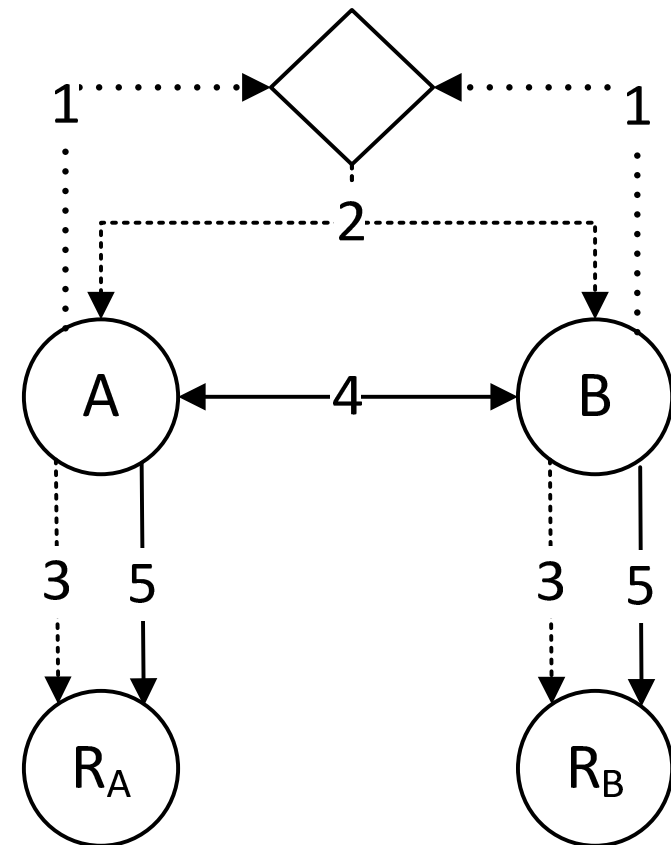




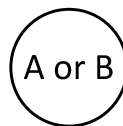
# Coordination mechanism 1

## • Three main steps:

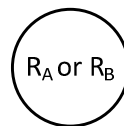
- Solve optimization problem
- Benefit sharing with a financial flow (4) between the business units
  - Predefined incentive rule
- Each business unit pays its own resource



Planning function



Collaborating business units



Resource of each business unit

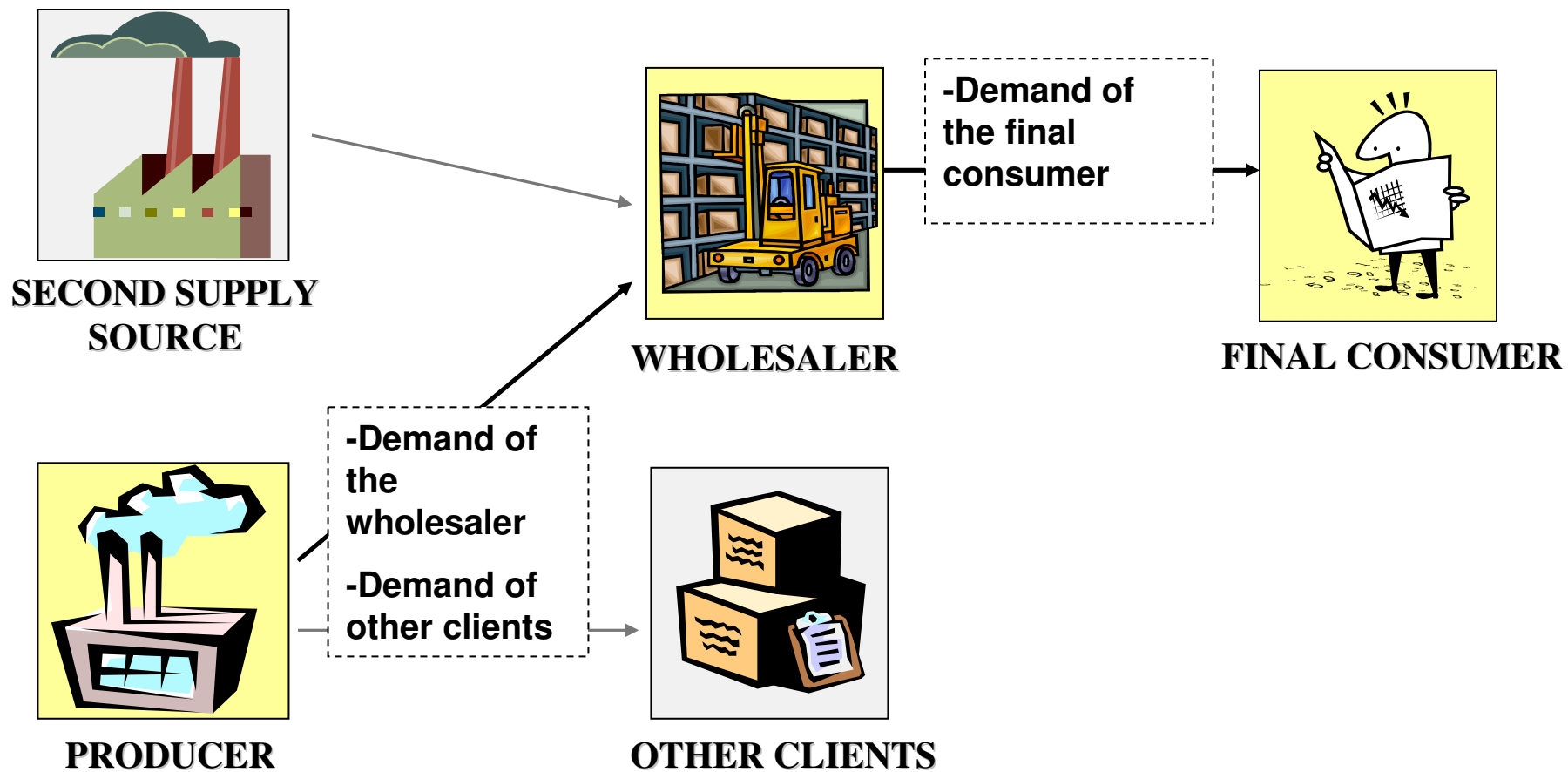
.....▶ Information flow

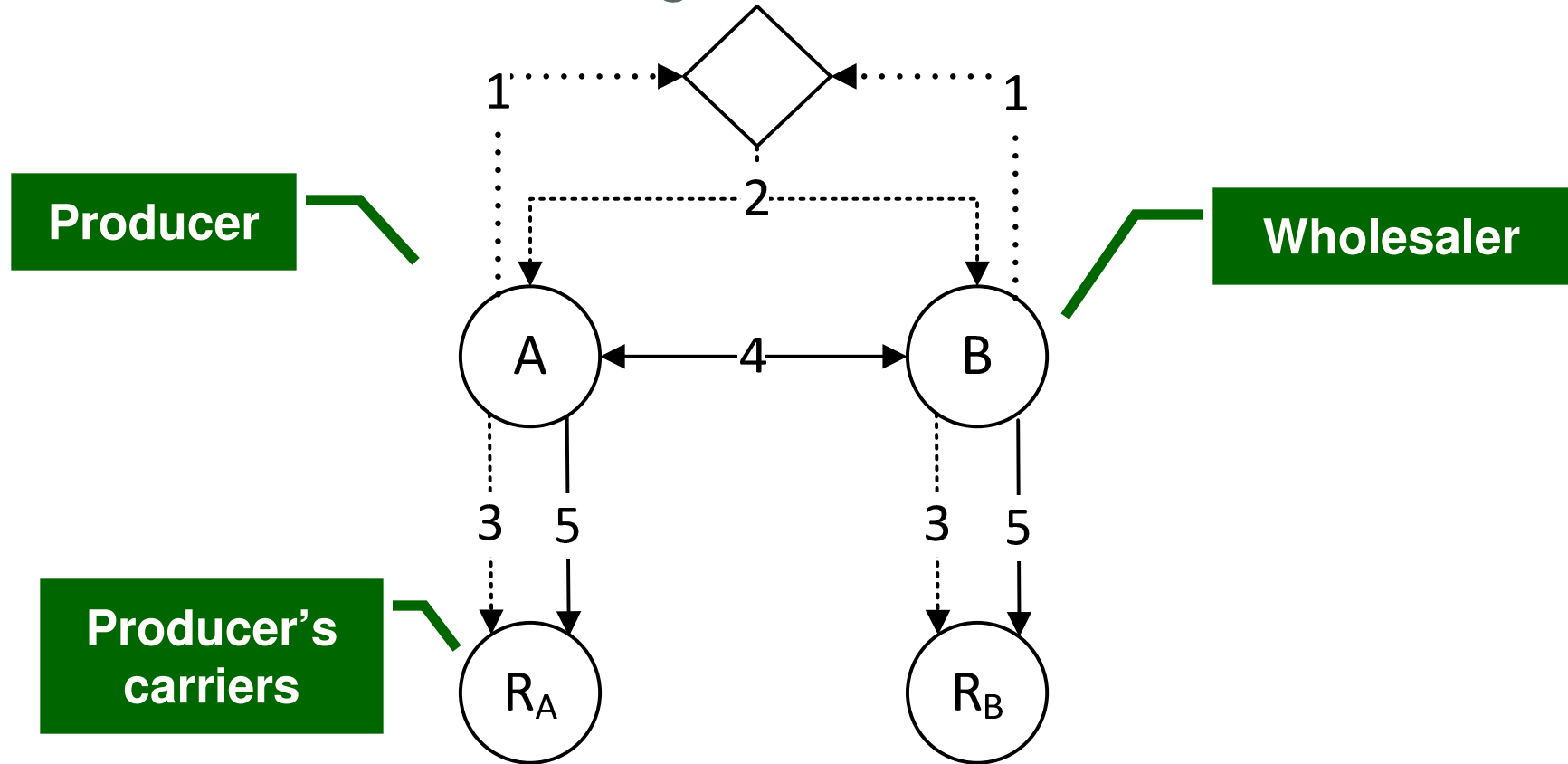
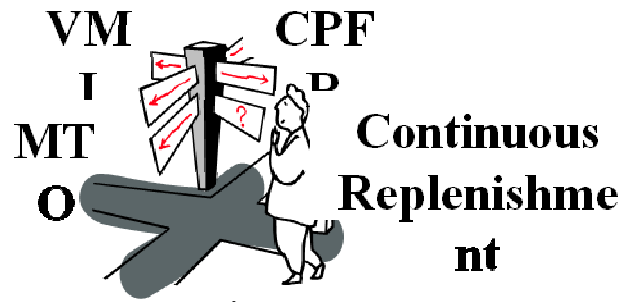
.....▶ Decision flow

——▶ Financial flow

1, 2,... flows numbering respects the chronological sequence of the mechanism

# Supply by a paper producer to a wholesaler (Lehoux *et al.*, 2009a)



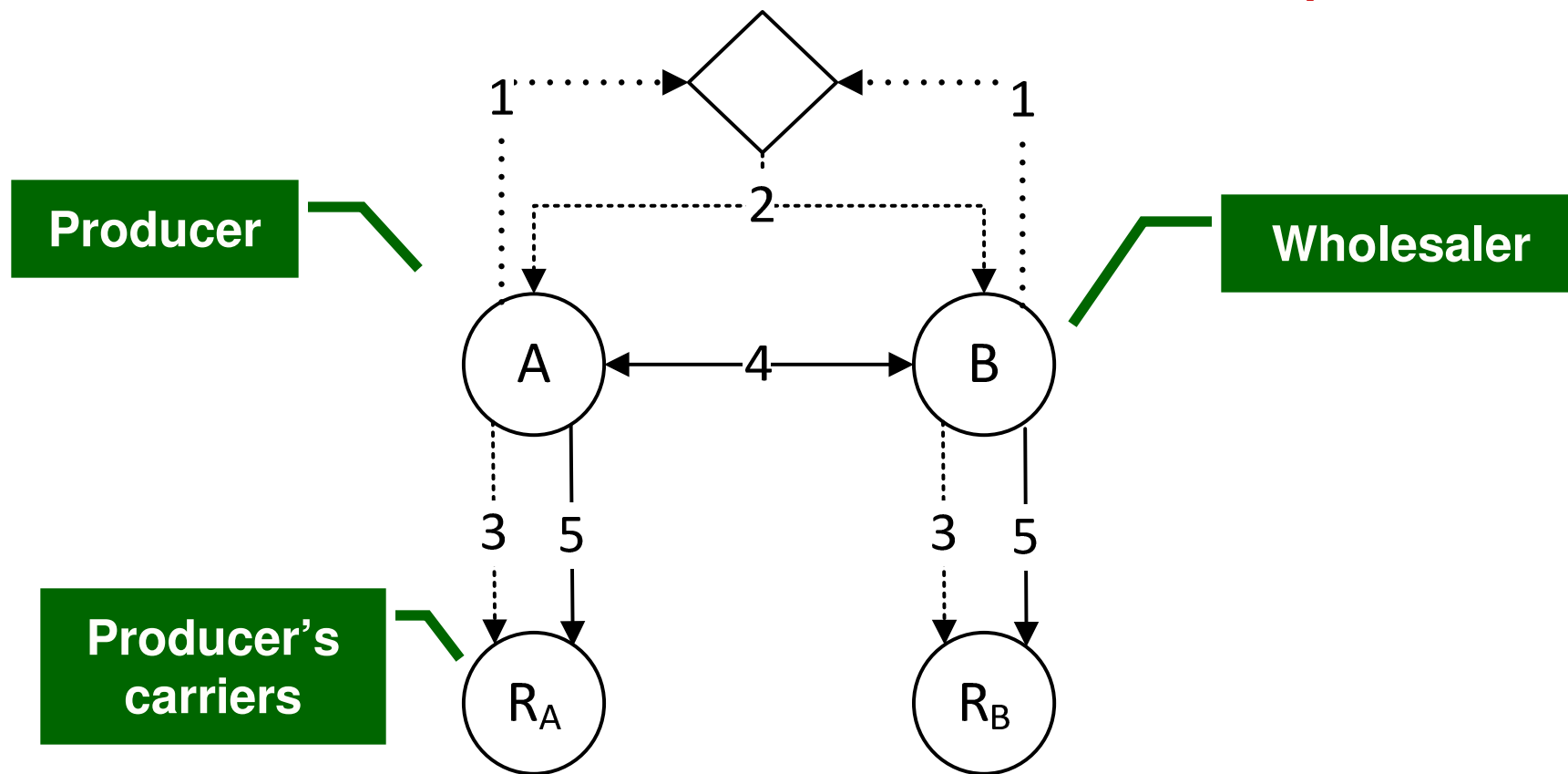


## Best approach

Producer: CPFR

Coalition: CPFR

Wholesaler: **continuous replenishment**

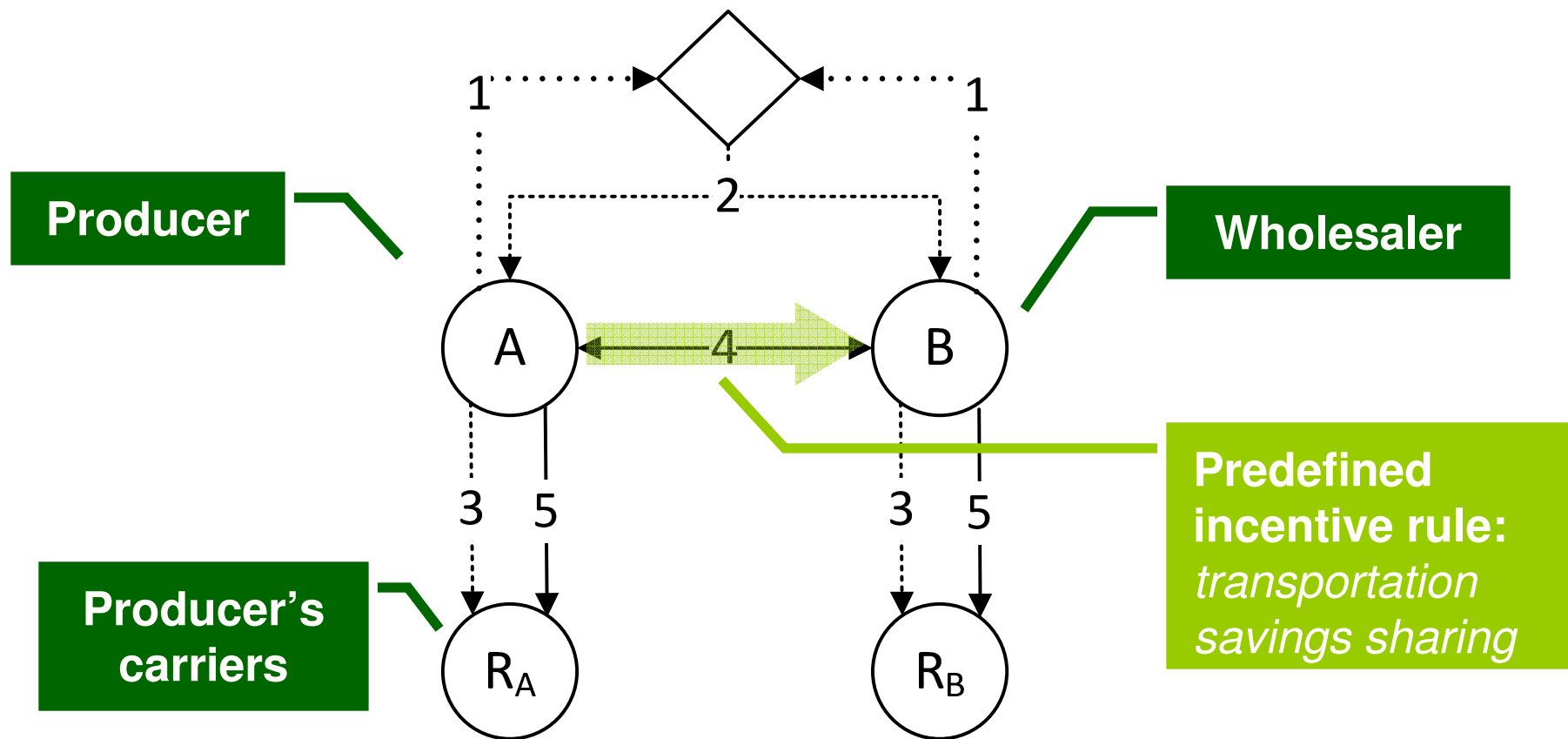


## Best approach

Producer: CPFR

Coalition: CPFR

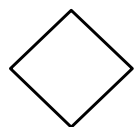
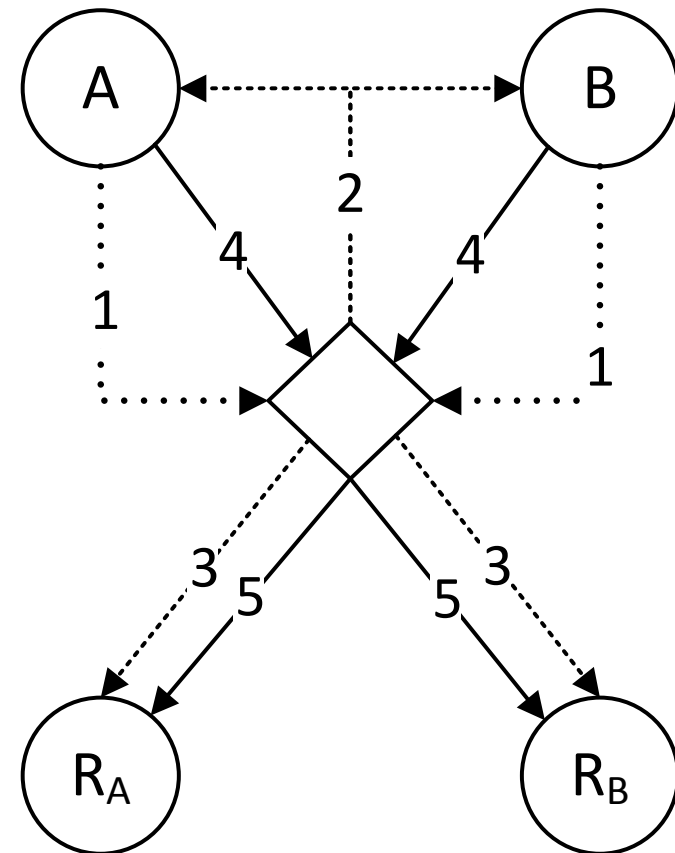
Wholesaler: CPFR



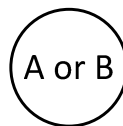
## Coordination mechanism 2

- **Three main steps:**

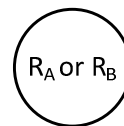
- Solve optimization problem
- Benefit sharing with an economic model
- Transfer of money from each business unit to the planning function to each resource



Planning function



Collaborating business units



Resource of each business unit

.....▶ Information flow

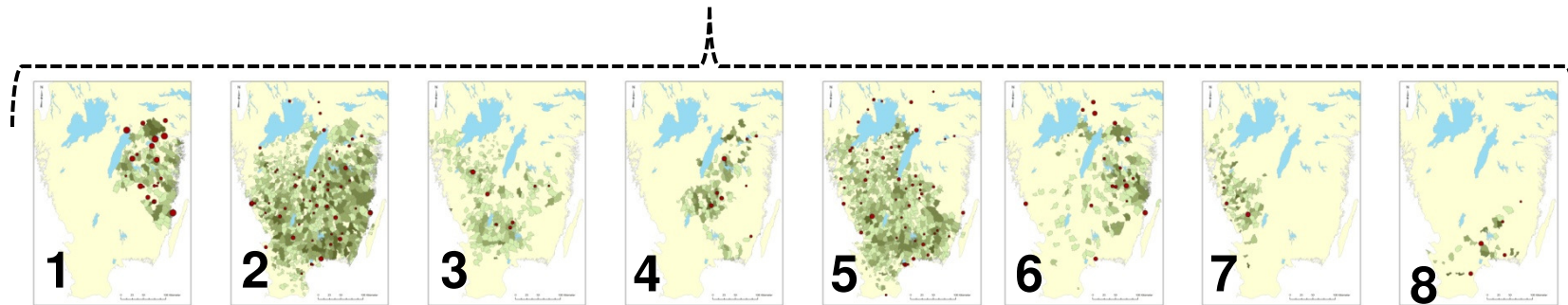
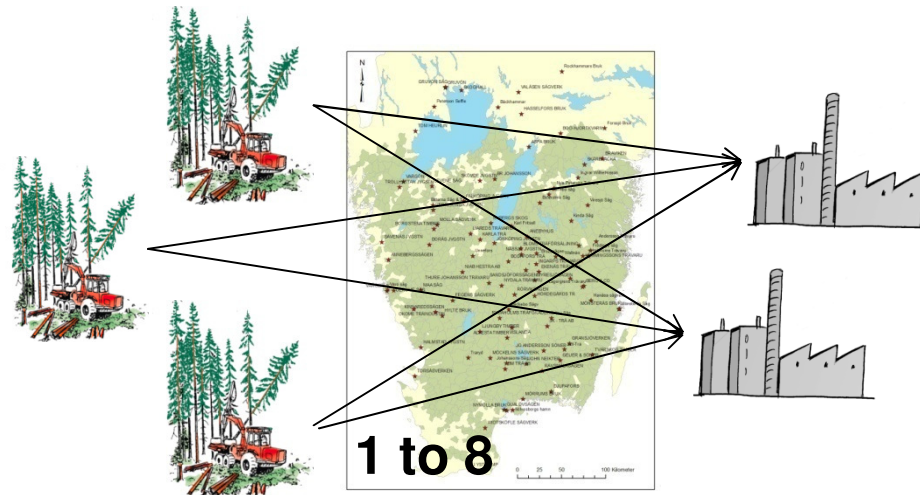
-----▶ Decision flow

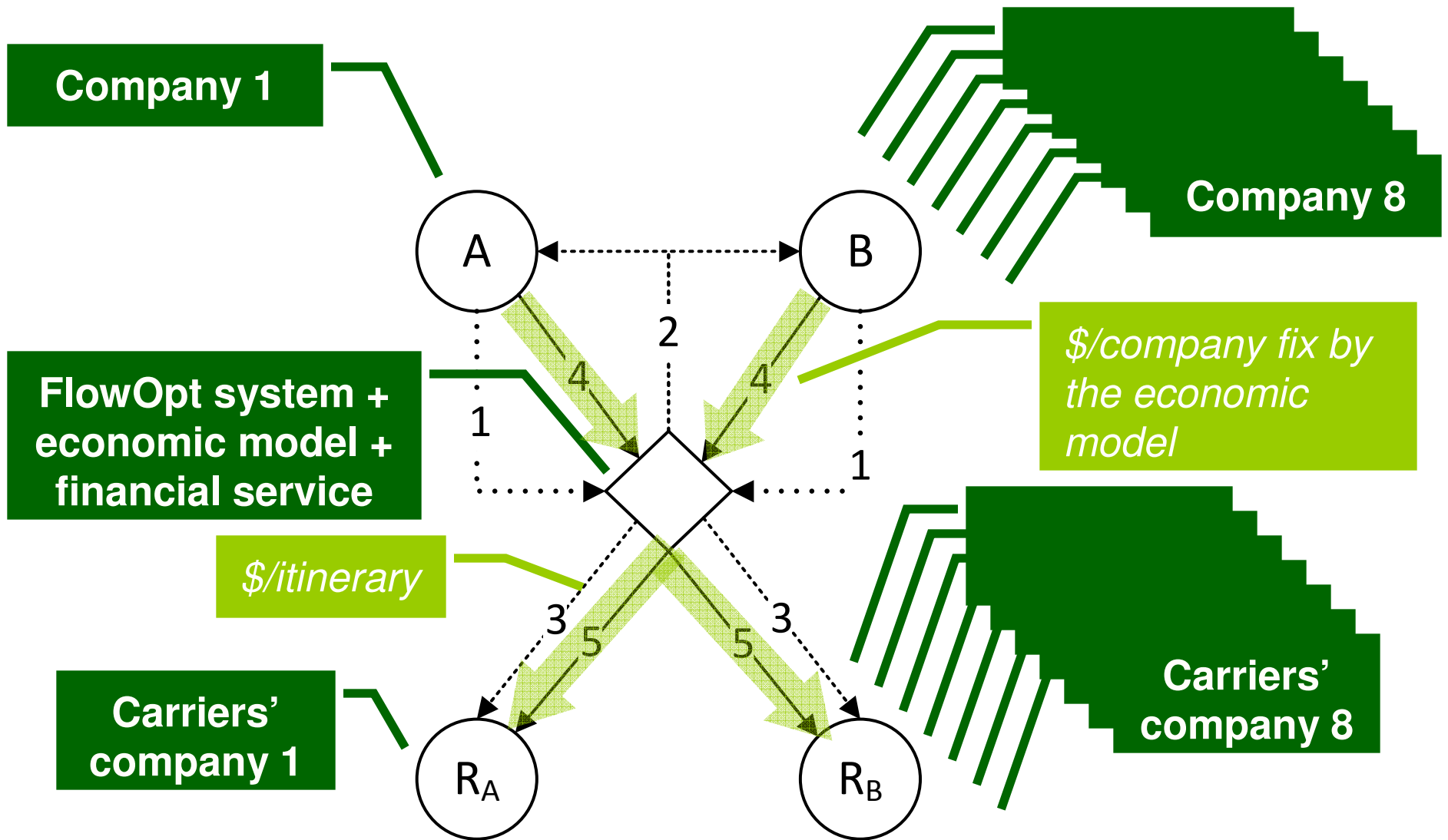
————▶ Financial flow

1, 2,... flows numbering respects the chronological sequence of the mechanism

# Wood exchange (Frisk *et al.*, 2009)

## FlowOpt system





## Results according to different economic models (Frisk *et al.*, 2009)

Company	Volume	Shapley	Shadow	Nucleo.	<b>EPM</b>
Company 1	9,0	5,1	4,1	3,4	<b>6,7</b>
Company 2	9,7	9,0	12,7	11,1	<b>8,8</b>
Company 3	11,2	13,5	14,2	14,0	<b>8,8</b>
Company 4	4,3	8,6	13,3	6,4	<b>8,8</b>
Company 5	0,2	5,7	-1,8	4,8	<b>8,8</b>
Company 6	19,9	9,2	11,7	8,3	<b>8,8</b>
Company 7	13,2	15,8	15,6	11,5	<b>8,8</b>
Company 8	14,0	6,9	9,1	4,6	<b>8,8</b>

## Equal Profit Method (Frisk *et al.*, 2009)

Relative savings:  $\frac{c(\{i\}) - y_i}{c(\{i\})} = 1 - \frac{y_i}{c(\{i\})}$ . Stable allocation  $c(\{i\}) \geq y_i$ .

Relative difference between two participants:  $\frac{y_i}{c(\{i\})} - \frac{y_j}{c(\{j\})}$

Minimize difference i.e.

$$\min f$$

$$\text{s.t. } f \geq \frac{y_i}{c(\{i\})} - \frac{y_j}{c(\{j\})}$$

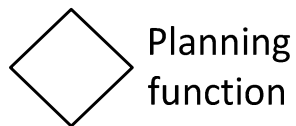
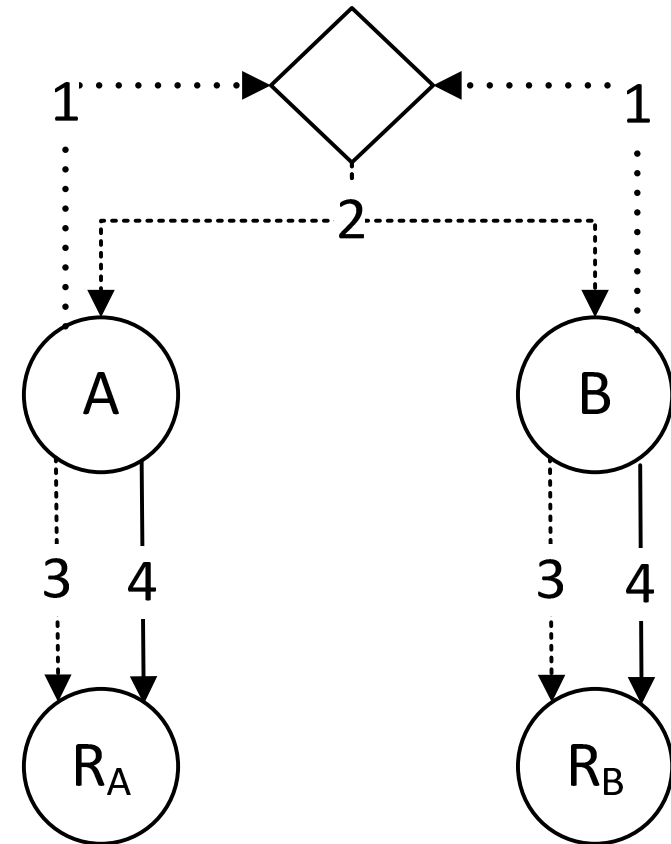
$$\sum_{j \in S} y_j \leq c(S), \quad S \subset N$$

$$\sum_{j \in N} y_j = c(N)$$

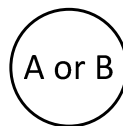
# Coordination mechanism 3

## • Two main steps:

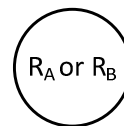
- Solve optimization problem with respect to an additional constraint related to benefit sharing
- Each business unit pays its own resource



Planning function



Collaborating business units



Resource of each business unit

.....▶ Information flow

.....▶ Decision flow

——▶ Financial flow

1, 2,... flows numbering respects the chronological sequence of the mechanism

## Wood exchange (Lehoux *et al.*, 2009b)

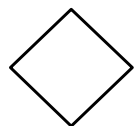
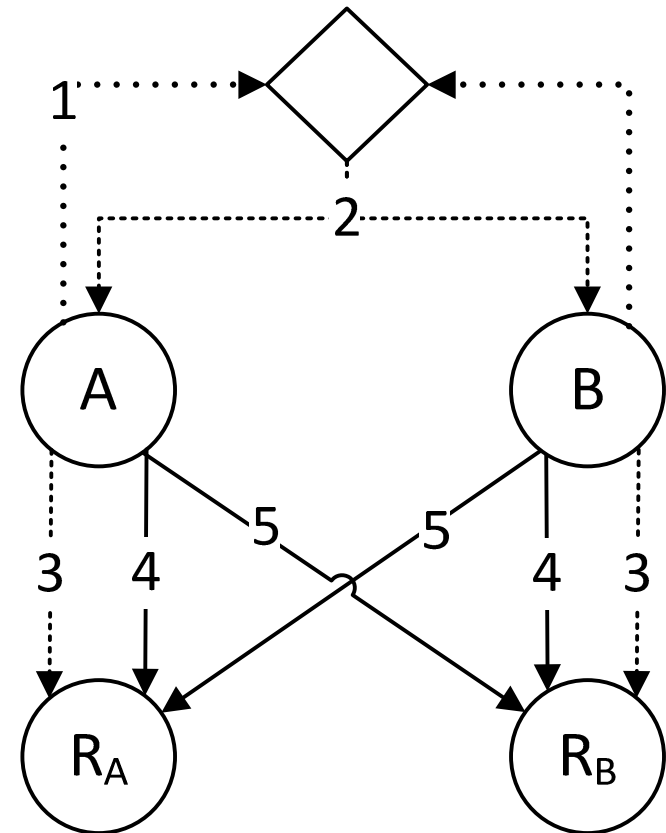
- 3 companies in a case studied by Frisk *et al.* (2009)
- Common optimization problem for the wood exchange problem with 'new' constraints related to benefit sharing
  - Each pair of companies must have the same relative saving
  - Each pair of companies must exchange the same volume
  - Each company is responsible for the transportation of its supply (to its own mills and others)
- The improvement in each month is in the range 5-20%. The decrease caused by the new constraints is low, less than 1-2%.



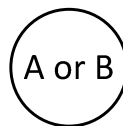
## Coordination mechanism 4

- **Two main steps:**

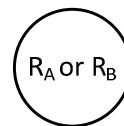
- Solve optimization problem and benefit sharing
- Each business unit pays the resources according to the value fixed by the optimization problem



Planning function



Collaborating business units



Resource of each business unit

.....▶ Information flow

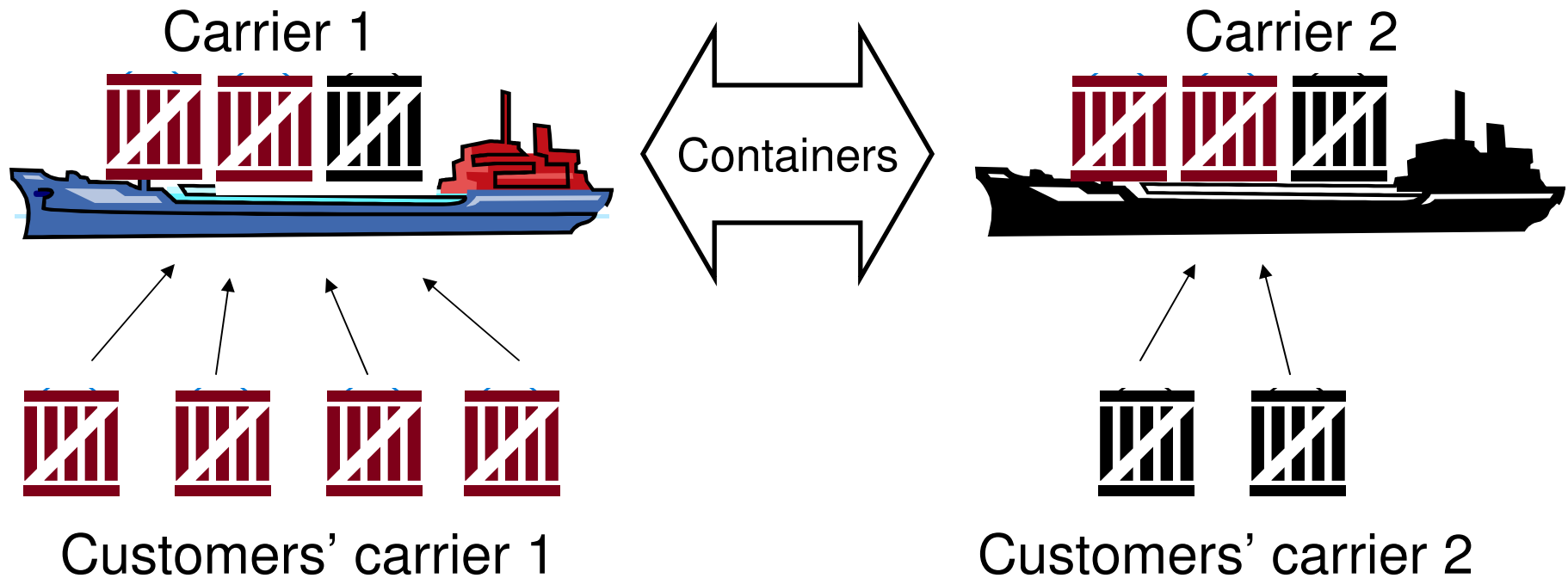
.....▶ Decision flow

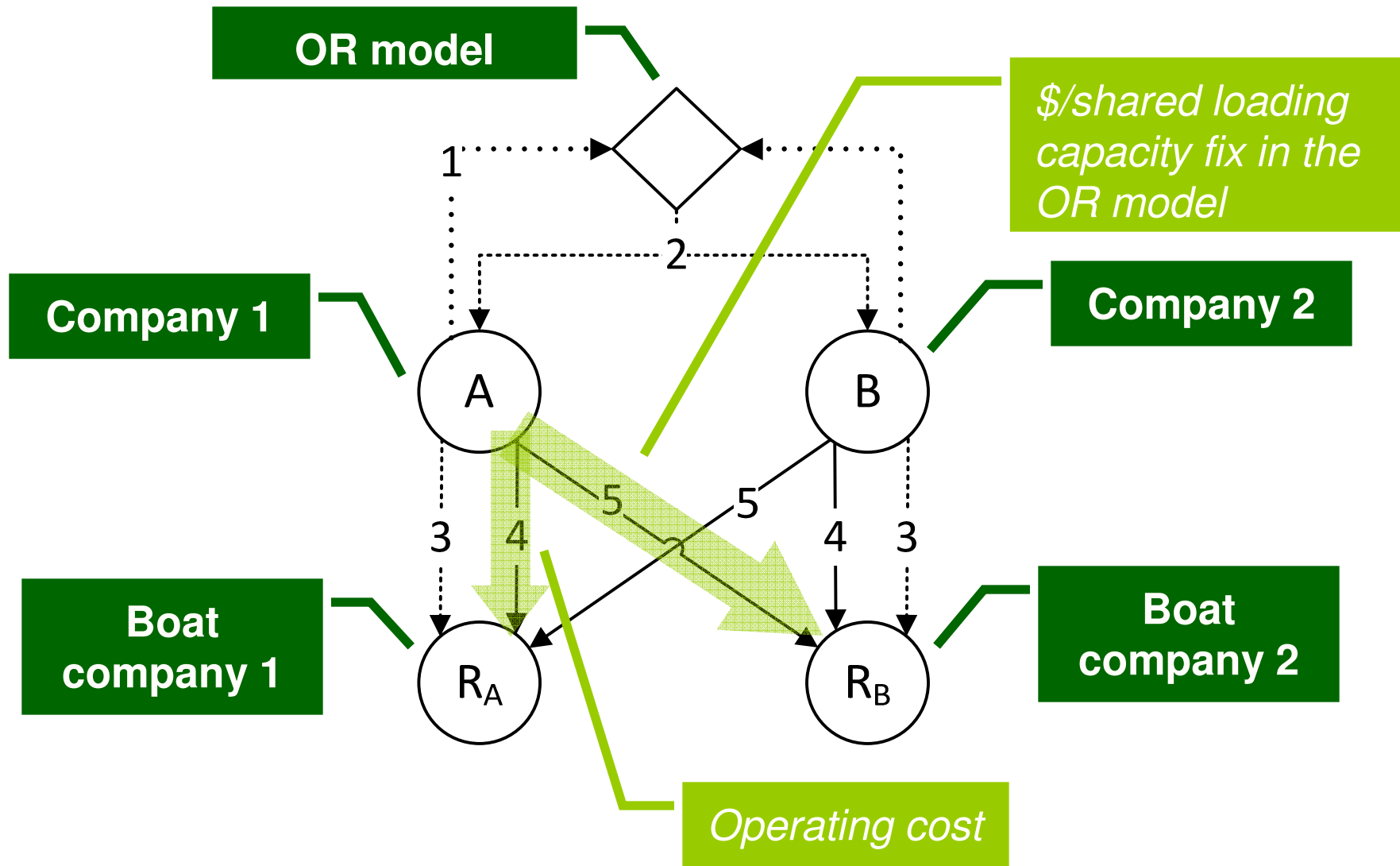
——▶ Financial flow

1, 2,... flows numbering respects the chronological sequence of the mechanism

## Carriers alliance in linear shipping (Agarwal and Ergun, 2008)

- Sea container carriers sharing the loading capacity of their ships

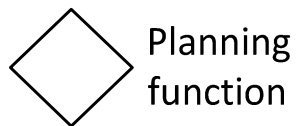
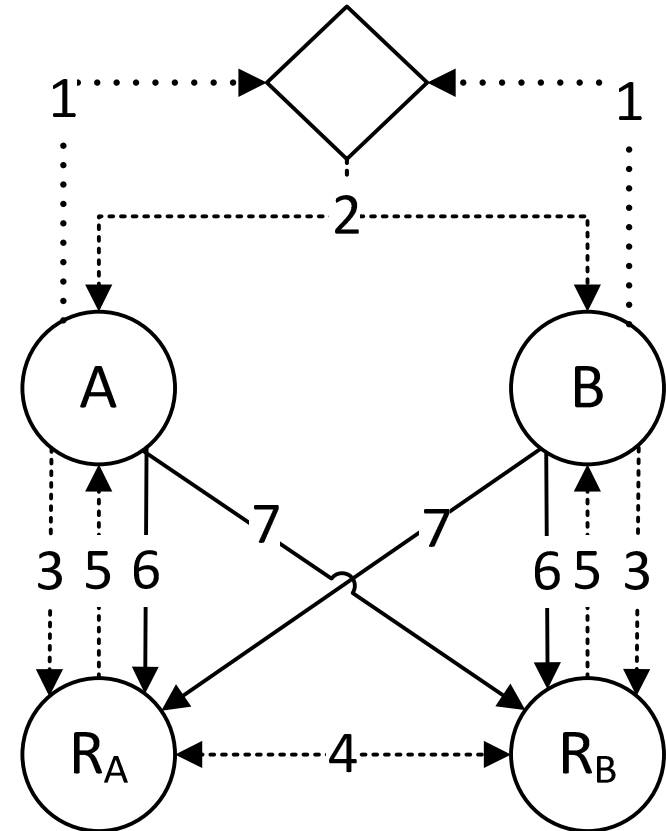




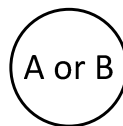
# Coordination mechanism 5

## • Three main steps:

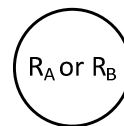
- Solve optimization problem (or a relaxation) to obtain a list of collaboration opportunities
- For each opportunity, resource agrees or not to collaborate at a given cost
- Each business unit pays the resources



Planning function



Collaborating business units



Resource of each business unit

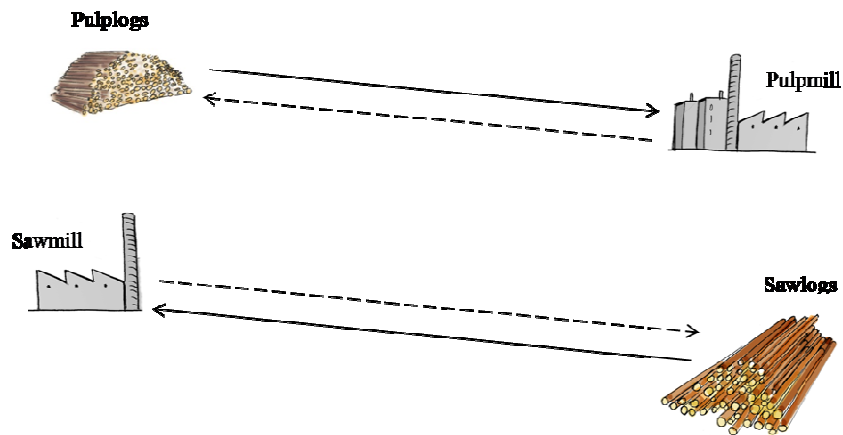
.....▶ Information flow

-----▶ Decision flow

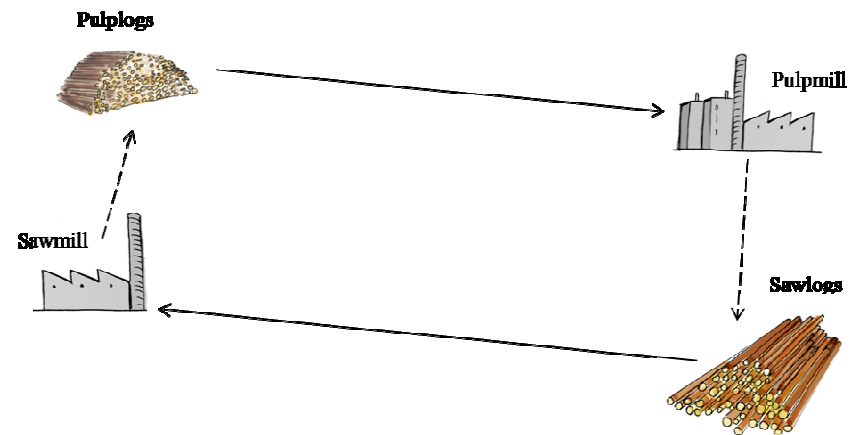
————▶ Financial flow

1, 2,... flows numbering respects the chronological sequence of the mechanism

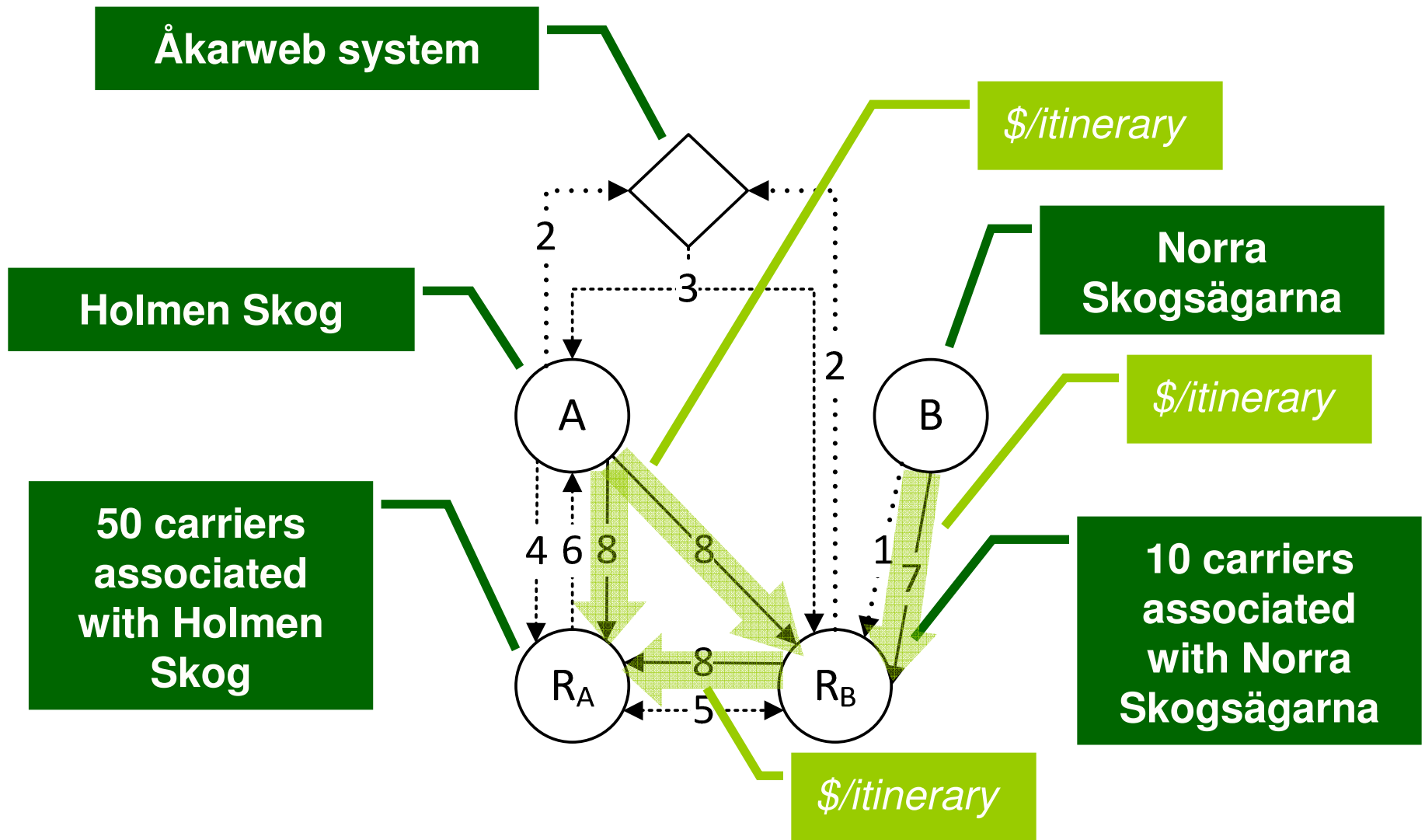
# Backhauling with the Åkarweb system (Eriksson and Rönnqvist, 2003)



**Individual plan**

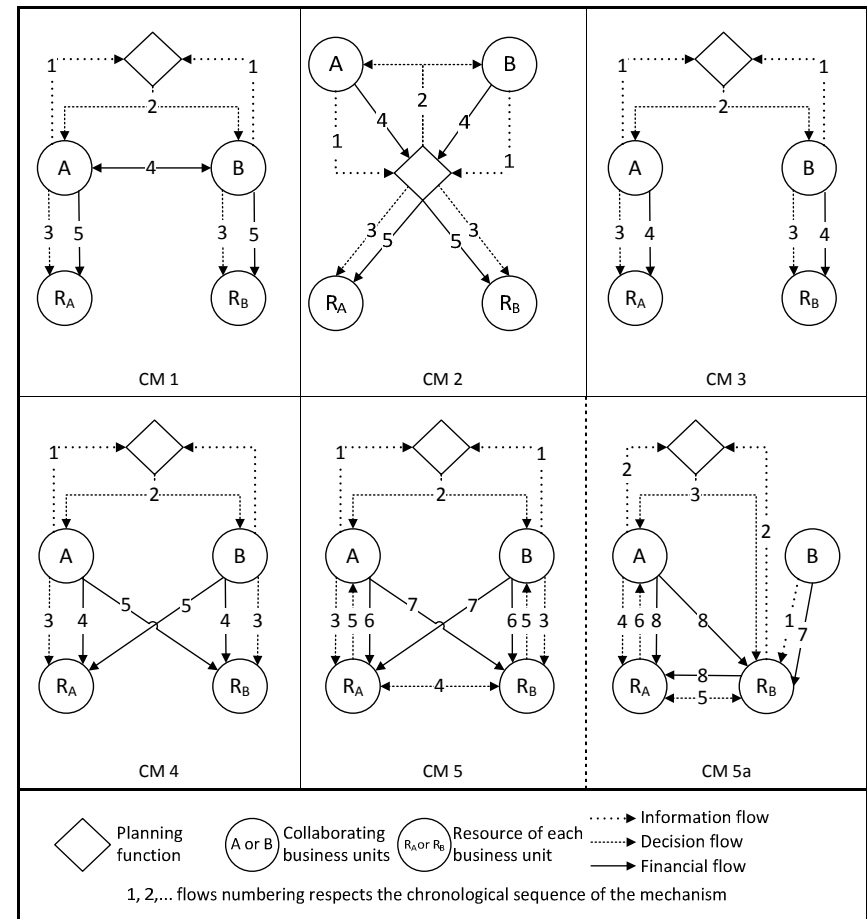


**Collaborative plan**



# Conclusion

- Collaboration in logistics can provide financial benefit (and others)
- Different **coordination mechanisms** exist to support the collaboration



## Acknowledgments

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