Coordination in Collaborative Logistics

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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)

New constraints:
- Limit on the total volume that can be exchanged
- Each company must remain the main supplier for its own mills
- Exchanges are pair-wise equal

(Usually) reduce the potential savings

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

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

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

Producer
Producer’s carriers

Producer

Producer’s carriers

Wholesaler

Wholesaler

A

B

R_A

R_B

1

2

4

3

5

3

5
Best approach
Producer: CPFR
Coalition: CPFR
Wholesaler: CPFR

Predefined incentive rule:
transportation savings sharing

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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

1, 2,... flows numbering respects the chronological sequence of the mechanism
Wood exchange (Frisk et al., 2009)

FlowOpt system

1 to 8

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

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<tr>
<th>Company</th>
<th>Volume</th>
<th>Shapley</th>
<th>Shadow</th>
<th>Nucleo.</th>
<th>EPM</th>
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</table>
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.

\[
\min f
\]

\[
s.t. \quad f \geq \frac{y_i}{c\{i\}} - \frac{y_j}{c\{j\}}
\]

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

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

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%.
FlowOpt system with new constraints

Company 1

Carriers’ company 1

Company 3

Carriers’ company 3

$/itinerary

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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

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

![Diagram showing carriers alliance in linear shipping](image-url)
OR model

$/shared loading capacity fix in the OR model

Company 1

Company 2

Boat company 1

Boat company 2

Operating cost

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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

1, 2,... flows numbering respects the chronological sequence of the mechanism
Backhauling with the Åkarweb system
(Eriksson and Rönnqvist, 2003)

Individual plan

Collaborative plan
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Åkarweb system

Holmen Skog

50 carriers associated with Holmen Skog

10 carriers associated with Norra Skogsägarna

$/itinerary

$/itinerary

$/itinerary

$/itinerary
Conclusion

• Collaboration in logistics can provide financial benefit (and others)

• Different coordination mechanisms exist to support the collaboration
Acknowledgments

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References