Global Supply Chains Coordination with Optimal Integration of Third Parties

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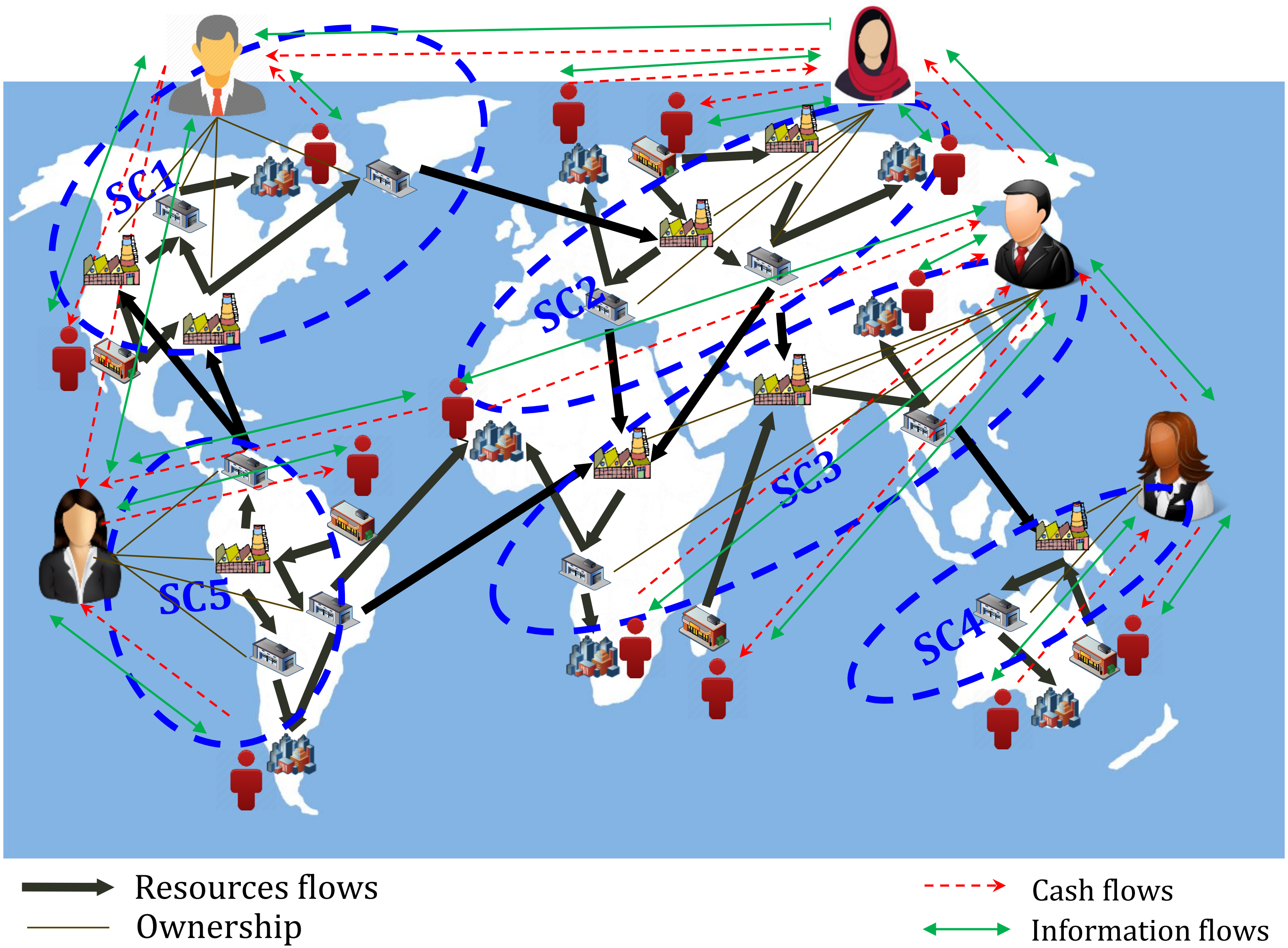
Global multi-enterprise supply chains



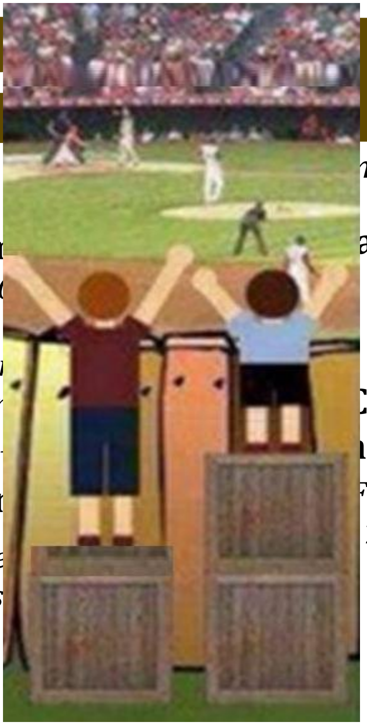
State-of-the-Art

Coordination

Non-cooperative approaches

Cooperative approaches

Stackelber



Nash Equilibrium game

Non-symmetrical

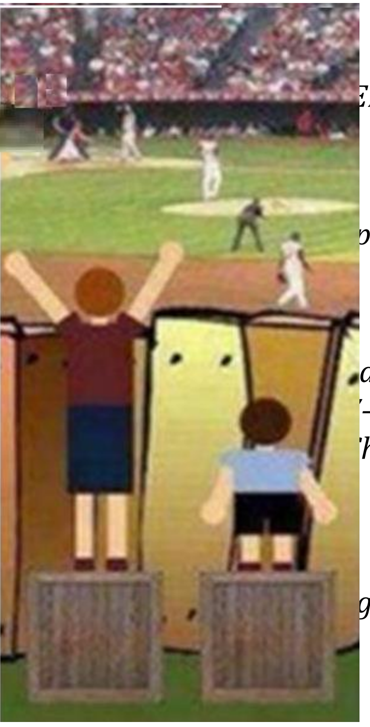
- **Bi-level optim**
  - Yue and You, (71,347–361
  - Garcia-Herrer Mehta, Grossr CACE,37, 202
- **Coordination**

  - Huang, He & Le Trans. in Op. Res

nmetrical roles: competence

- **air allocation of profit**
  - Ortiz-Gutiérrez, Giarola, Shah, Bezzo, 2015, CACE,37, 2255-2260
- **Competition between new and existing SCs**
  - Feyzian-Tary, Razmi & Sangari, 7, IJLSM, 26 (4), 515 – 544.

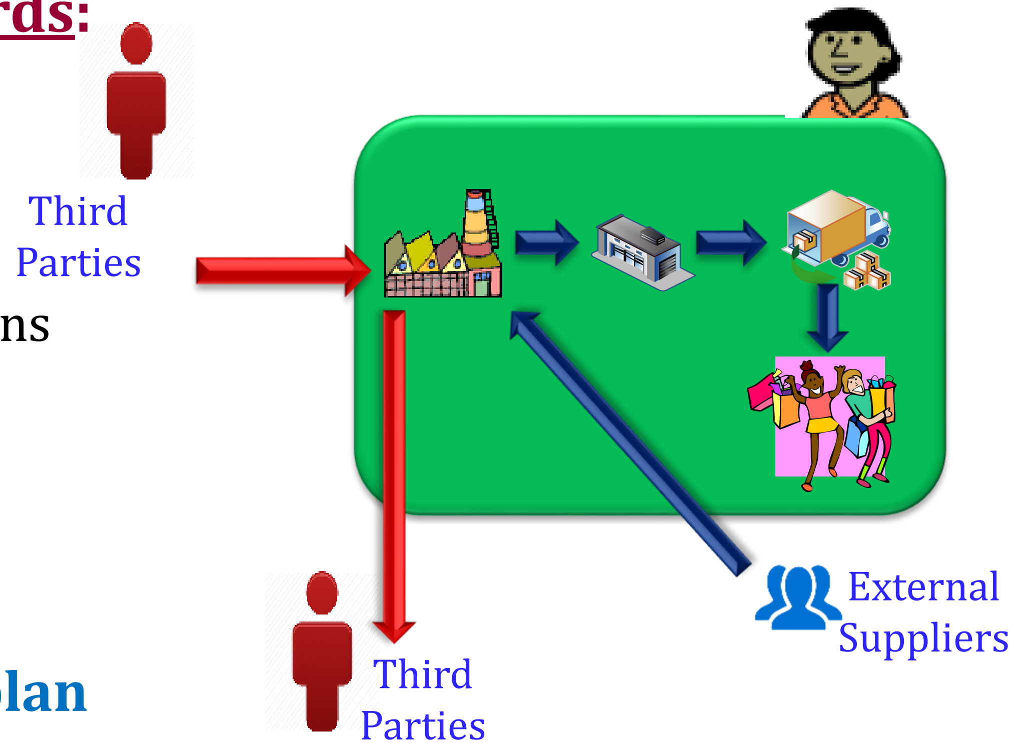
- **Multil**
  - Brunau EM, 4 (3), 256-270
- **Risk-s**
  - Inderfu pectrum, 36: 525–
- **Multi-**
  - Banas a, Barbosa- Póvoa – 32
  - Singh, hem Res 53(39
- **Fair pr**
  - Liu and ga, In press.



Problem statement

Current practice <u>disregards</u>:

- Detailed operation
- Echelon characteristics
- Independent objectives
- Simple economic transactions
- Average pricing



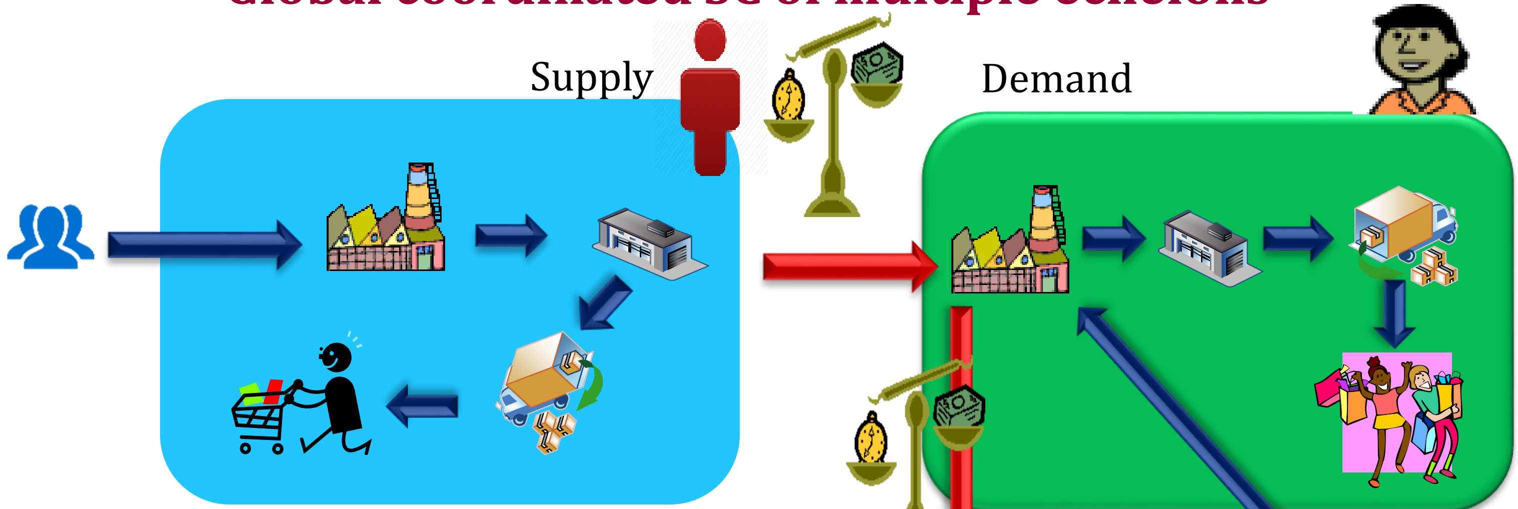
- Raw materials and utilities suppliers
- Clients
- waste and recovery systems
- ...

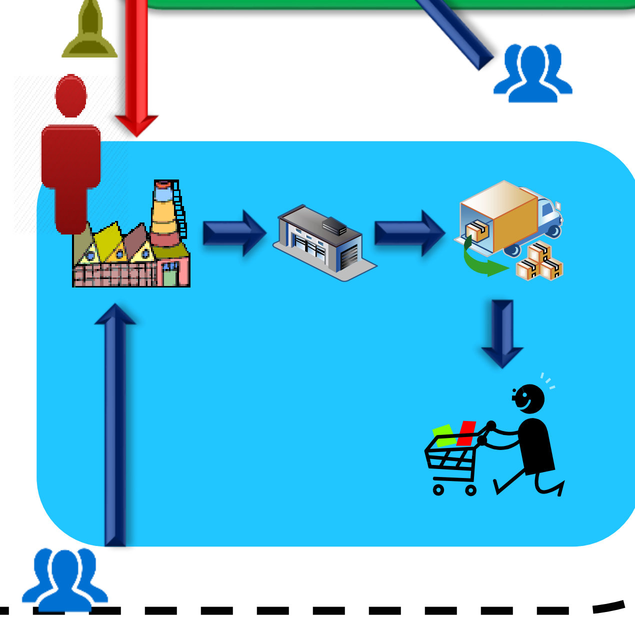
➔ Not sufficient to obtain a **global master plan**

<u>Objective:</u> ***To develop a global coordination generic model able to optimize the overall SC planning problem***

Global coordination with third parties

Global coordinated SC of multiple echelons





Methodological framework

Cooperative-based coordination

- Incorporating supportive enterprises as **full SCs.**
- Partitioning the SC into echelons.
- **Coalition** towards the whole objective
- Comparison: **typical approach vs. coordinated.**
- **Tactical** and economic decisions.

Mathematical formulations: a holistic tactical model

$$InD_{r',e',t} \le \sum_{\substack{r'\in R \\ r'\ne r}} fac_{r,r',e}.PRD_{r',e,t} \qquad \forall r\in R, e\in E, e'\in E, t\in T$$

→ Coordination

$$\min \quad TCOST = \sum_{e\in E} COST_e \qquad \forall e\in E$$

→ Objective function

$$COST_e = \sum_{t\in T} CRM_{e,t} + CPR_{e,t} + CST_{e,t} + CTR_{e,t} \qquad \forall e\in E$$

→ Cost

$$CRM_{e,t} = \sum_{r\in R} P_{r,e,t}.Q_{r,e,t} \qquad \forall e\in E, t\in T$$

→ RM cost

$$CPR_{e,t} = \sum_{r\in R} upr_{r,e,t}.PRD_{r,e,t} \qquad \forall e\in E, t\in T$$

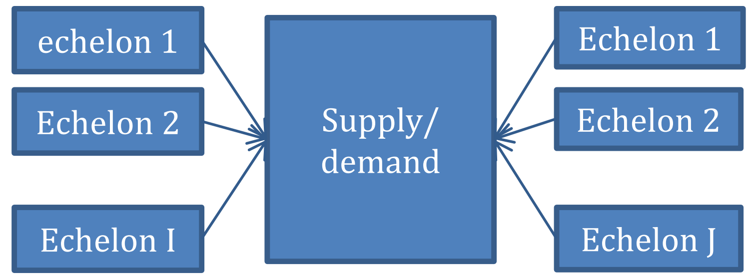
→ Production cost

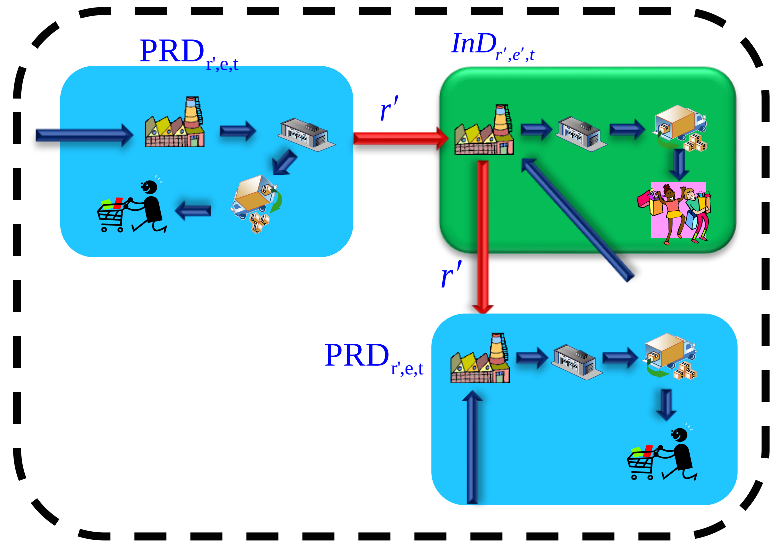
$$CST_{e,t} = \sum_{r\in R} ust_{r,e,t}.ST_{r,e,t} \qquad \forall e\in E, t\in T$$

→ Storage cost

$$CTR_{e,t} = \sum_{r\in R} \sum_{\substack{e'\in E \\ e'\ne e}} dis_{e,e'}.utr_{r,e,e'}.DLV_{r,e,e',t} \qquad \forall e\in E, t\in T$$

→ Distribution cost





Sets:

- *Echelons:* ***E*** (production plant, DC, market,...)
- *Resources:* ***R*** (RM, product, energy, cash,...)

Constraints:

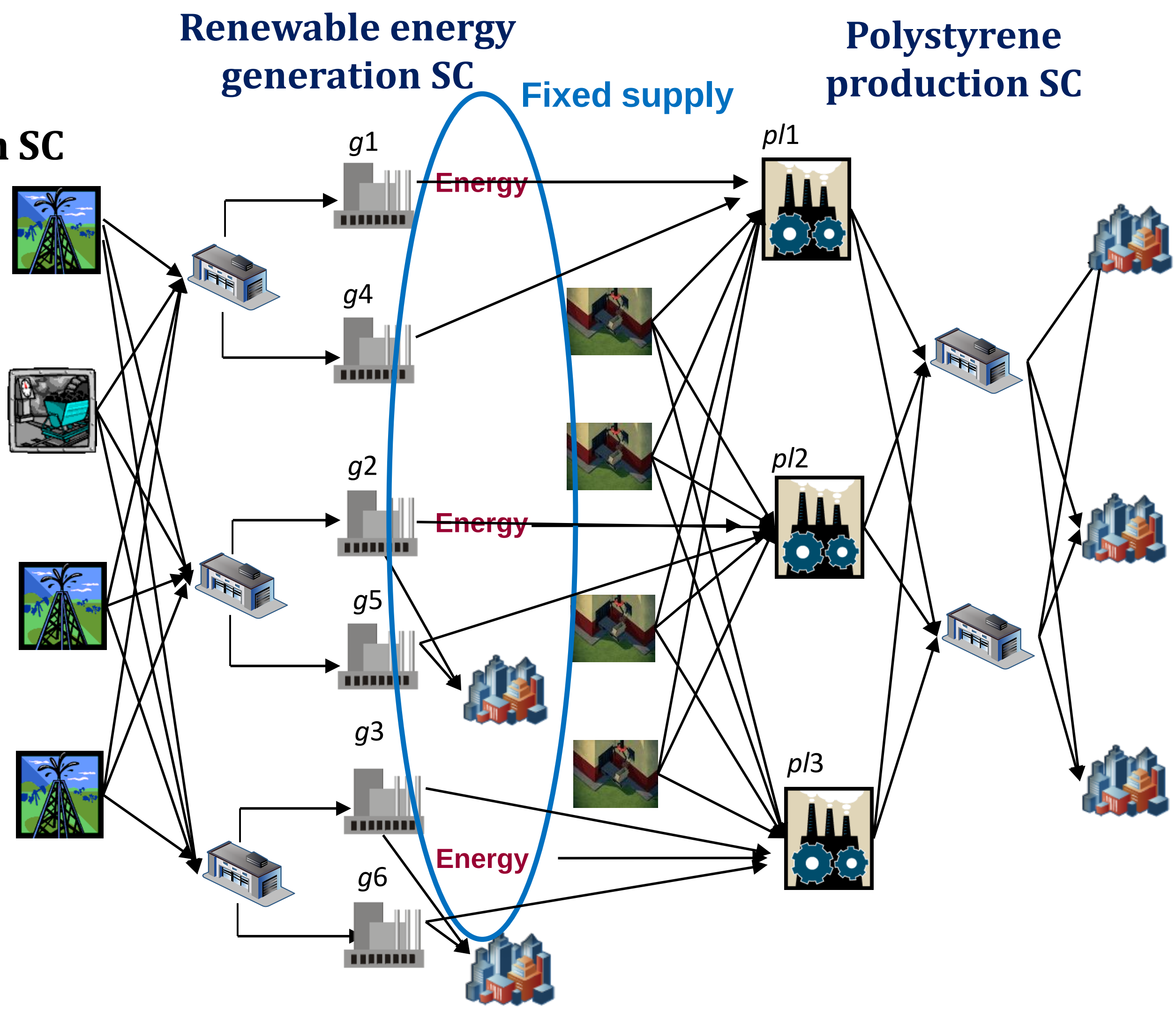
Resources balance, correlations, Capacities, ...)

Global coordination- Results

Case study

- **Polystyrene production SC**
  - 3 production sites
  - 2 storage centers
  - 3 markets
  - 4 RM suppliers
  - WWTP
  - 2 products

- **Energy generation SC**
  - 6 energy generation sites
  - 3 storage centers
  - 4 RMs (biomass and coal)
  - 2 fixed clients
  - 3 polystyrene markets



Detailed master plan: RM purchase; production; storage; and distribution levels

Global coordination- Results

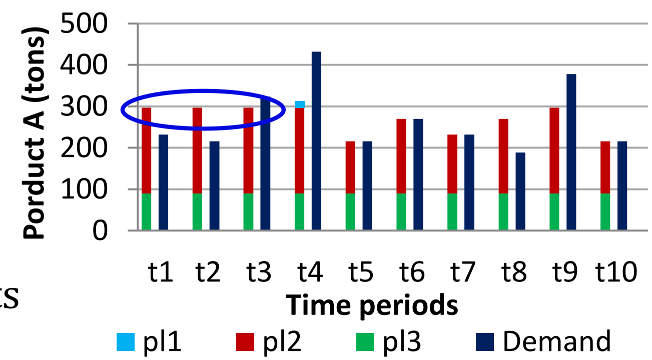
✓ 2 optimization scenarios

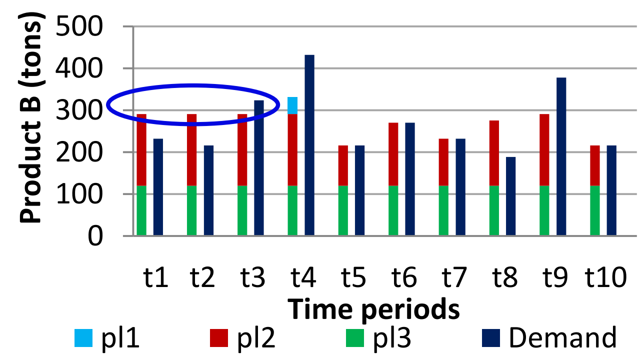
Optimization	Current practice	Coordination
Minimize Cost (polystyrene SC)	✓	-
Minimize Cost (energy generation SC)	✓	-
Minimize entire SC Cost	-	✓

Polystyrene production

❑ **Current practice**

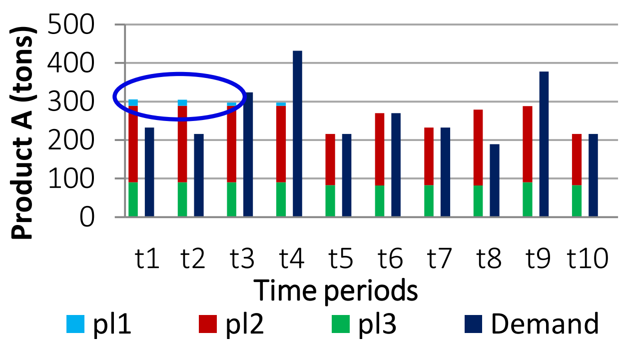
- ○ Overloading plants
- ○ Biased solutions
- ○ Infeasibility
- ○ Overload energy plants

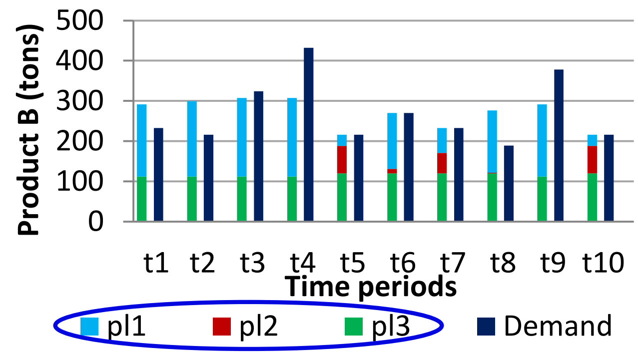




❑ **Coordination**

- ○ Reallocation plants
- ○ Reduce energy loads

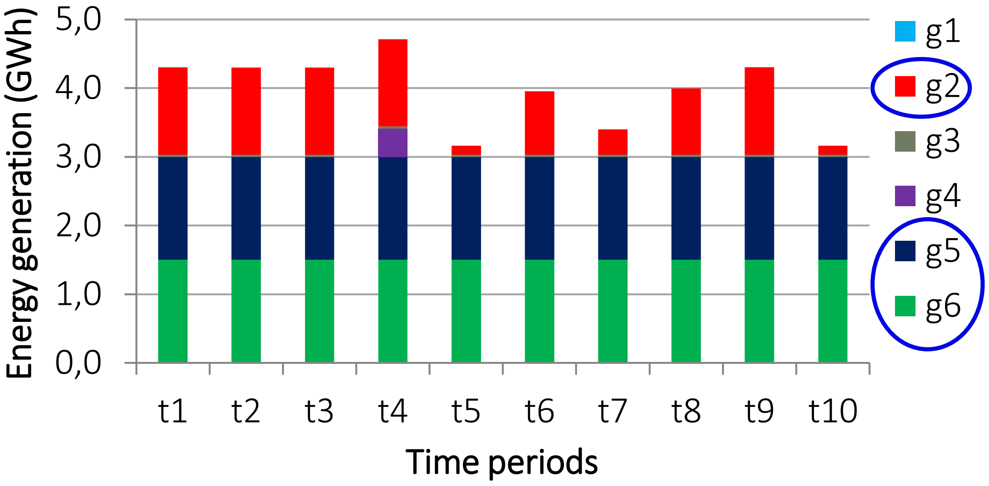




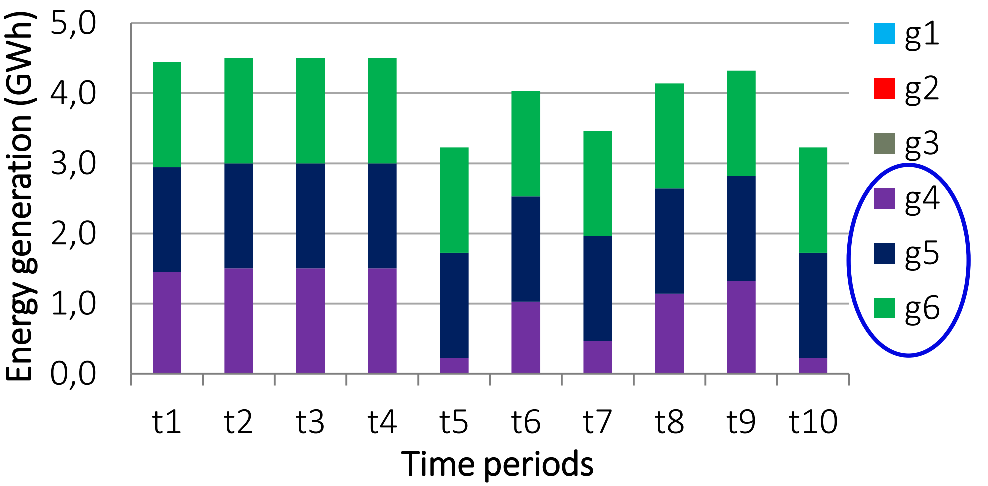
Global coordination- Results

Energy generation

- ❑ **Current practice**
  - Expensive choices
  - Less flexibility



- ❑ **Coordination**
  - Flexible energy loading
  - Cheaper choices



The coordination leads to flexible and feasible decisions for all actors

Global coordination- Economic analysis

❑ Polystyrene SC cost

0.42 %

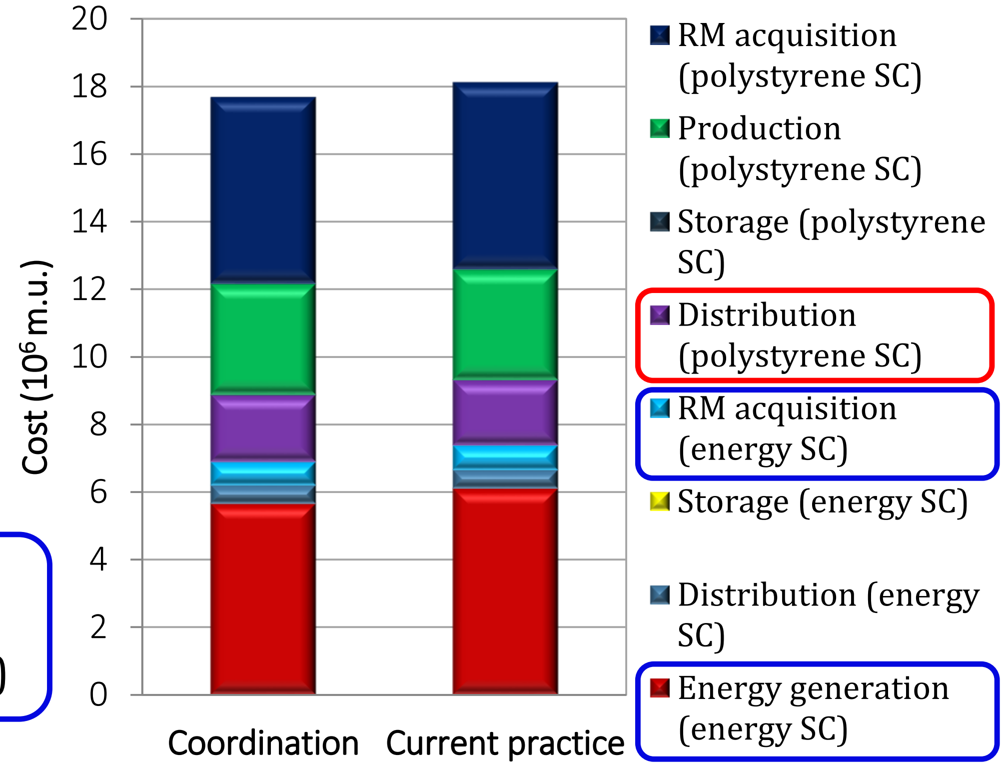
Distribution: **+2%** (45 x1

❑ Energy SC cost

6.95 %

RM purchase: **-5 %** (34 x10 u)

Energy generation: **-8%** (443 x10 ^{3} m.u)

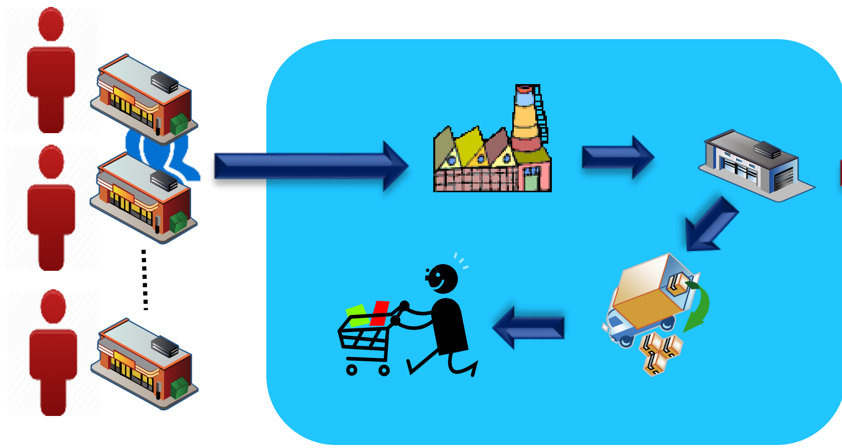


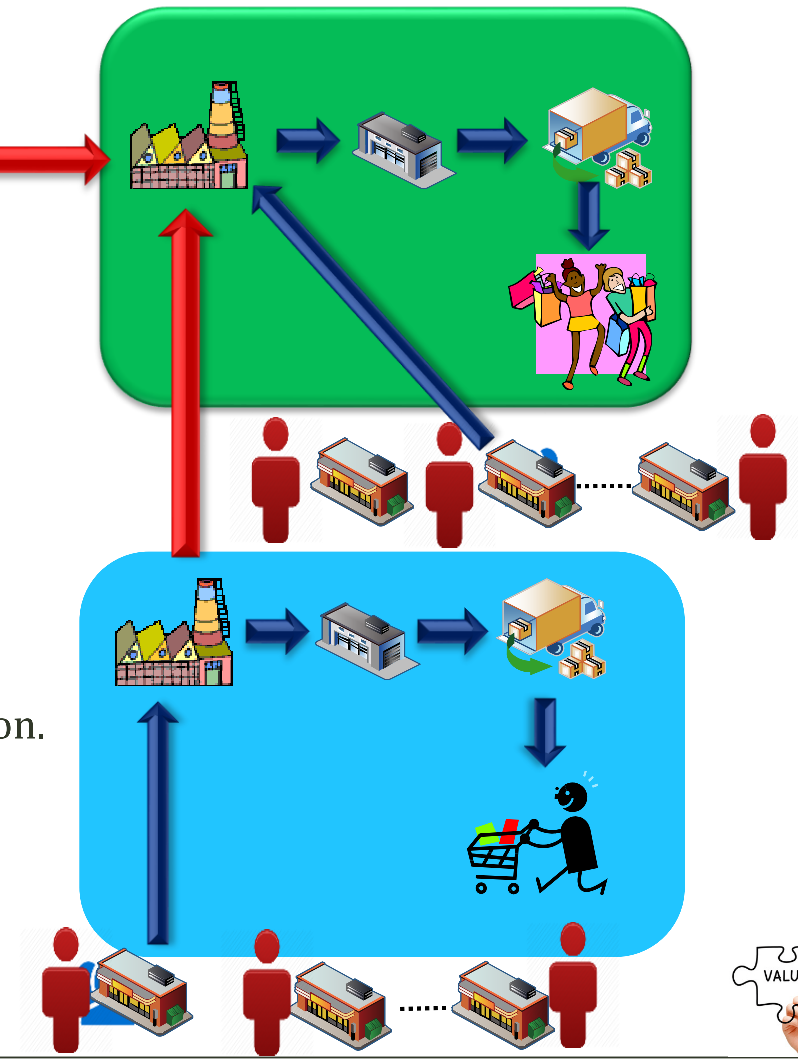
Total savings 2.5% (434 x10 ^{3} m.u)

Unlike the current approaches, the **coordination** based on **detailed description** of all participants leads to **less total cost** and **less resource consumption** for the same market requirements.

Optimal integration of third parties

Objective: ***To develop new joint collaboration tools with different competitive third parties in a coordinated SC environment***





Methodological framework

- **Global coordination**
  - **Pricing**: joint collaboration tool.
  - **Competition:** external actors.
  - **Commercial strategies:** price policy
  - **Trade-off:** commercial strategy vs SC operation.
- **Optimization and simulation**
  - Pricing **approximation** models.
  - **Traditional vs. pricing** models.
  - **Tactical** and economic decisions

Mathematical formulations

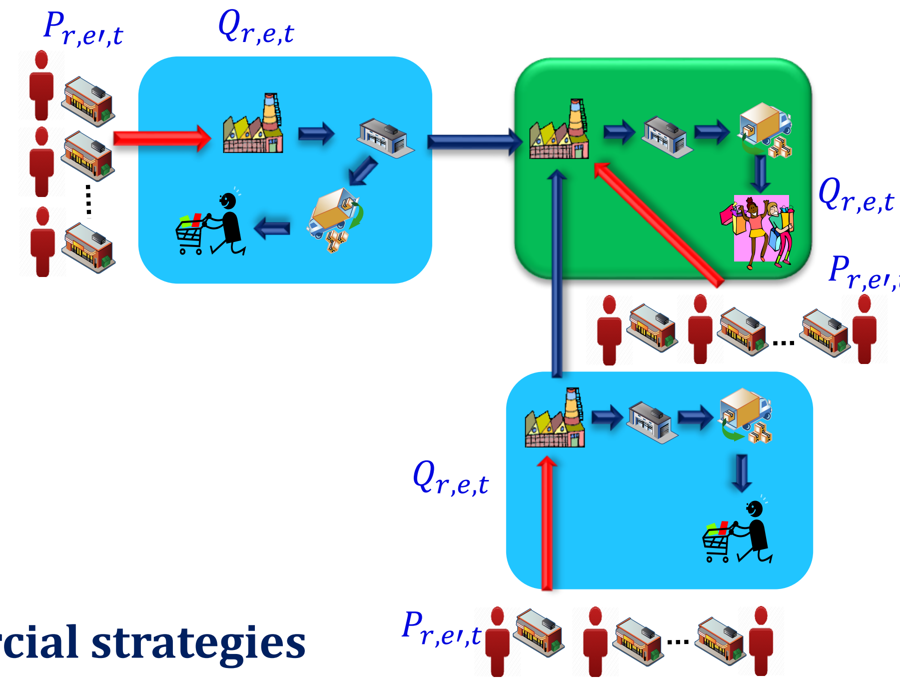
Modelling basis

Objective function

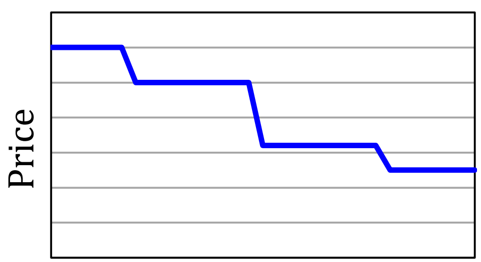
$$\min \sum_{e \in E} \sum_{t \in T} CRM_{e,t} + CPR_{e,t} + CST_{e,t} + CTR_{e,t}$$

$$CRM_{e,t} = \sum_{\substack{e' \in D \\ e' \neq E}} \sum_{r \in R} P_{r,e',t} \, Q_{r,e',e,t} \qquad \forall e \in E; t \in T$$

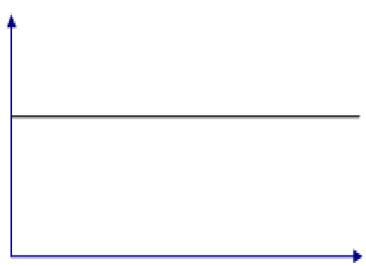
Price Quantity

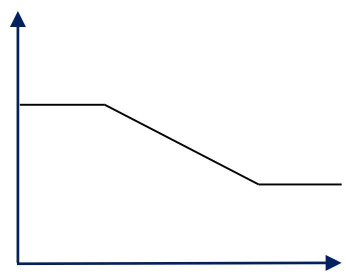


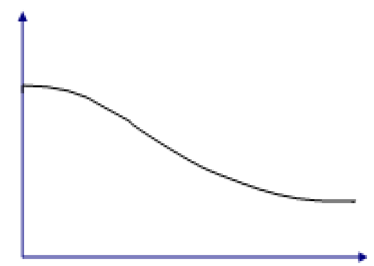
Price policy: as basic element of **commercial strategies**



Quantity demanded


Average fixed


Piecewise

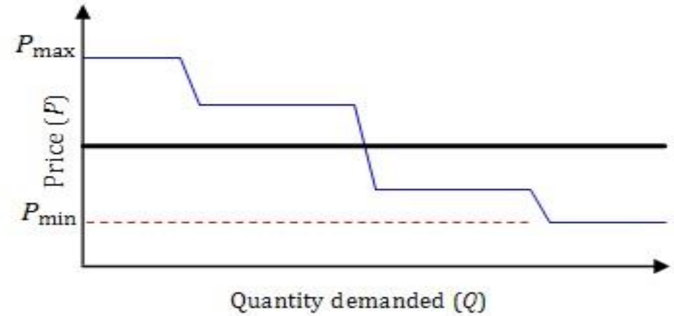

Polynomial

Commercial strategies

Pricing approximation models

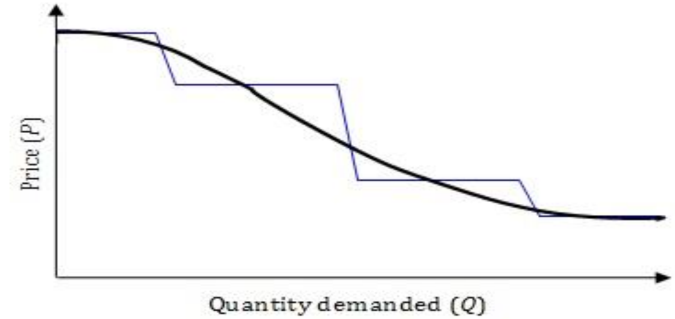
i) Average fixed (current practice)

$$P_{r,e',t} = \sum_{r \in R} (P^{max}_{r,e',t} + P^{min}_{r,e',t}) / 2) \quad \forall e' \in D; e' \in E; e' \neq E; t \in T$$



ii) Polynomial pricing

$$P_{r,e',t} = \sum_{a=1}^{A} c_{a,r} . (Q_{r,e',e,t})^{A-a} \quad \forall r \in R; e' \in D, e \in E; e' \neq E; t \in T$$



iii) Piecewise pricing

$$\sum_{n \in N} x_{r,e',t,n} \leq 1 \quad \forall r \in R; e' \in D; e \in E; e' \neq e; t \in T$$

$$x_{r,e',t,n} . Q^{max}_{r,e',e,t,n-1} \leq Qn_{r,e',e,t,n} \leq x_{r,e',t,n} . Q^{max}_{r,e',e,t,n}$$

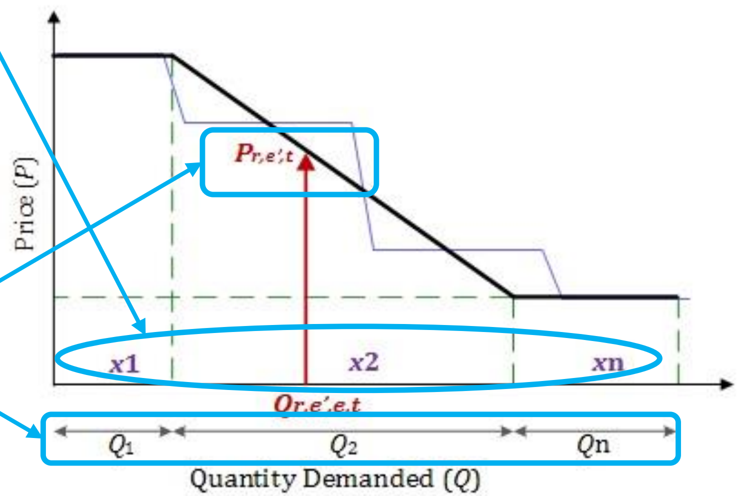
$$\forall r \in R; e' \in D; e \in E; n \in N; t \in T$$

$$x_{r,e',t,n} . P^{max}_{r,e',t,n} \leq Pn_{r,e',t,n} \leq x_{r,e',t,n} . P^{max}_{r,e',t,n}$$

$$\forall r \in R; e' \in D; n \in N; t \in T$$

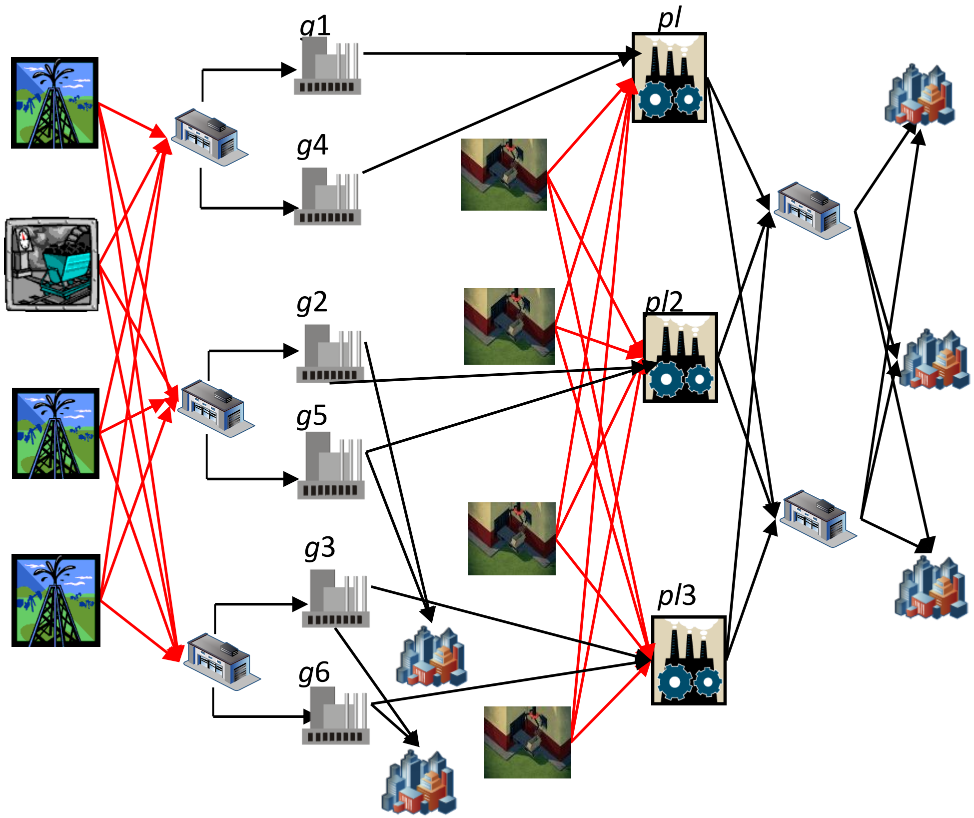
$$Q_{r,e',e,t} = \sum_{n \in N} Qn_{r,e',e,t,n} \quad \forall r \in R; e' \in D; e \in E; e' \neq e; t \in T$$

$$P_{r,e',t} = \sum_{n \in N} Pn_{r,e',t,n} \quad \forall r \in R; e' \in D; t \in T$$

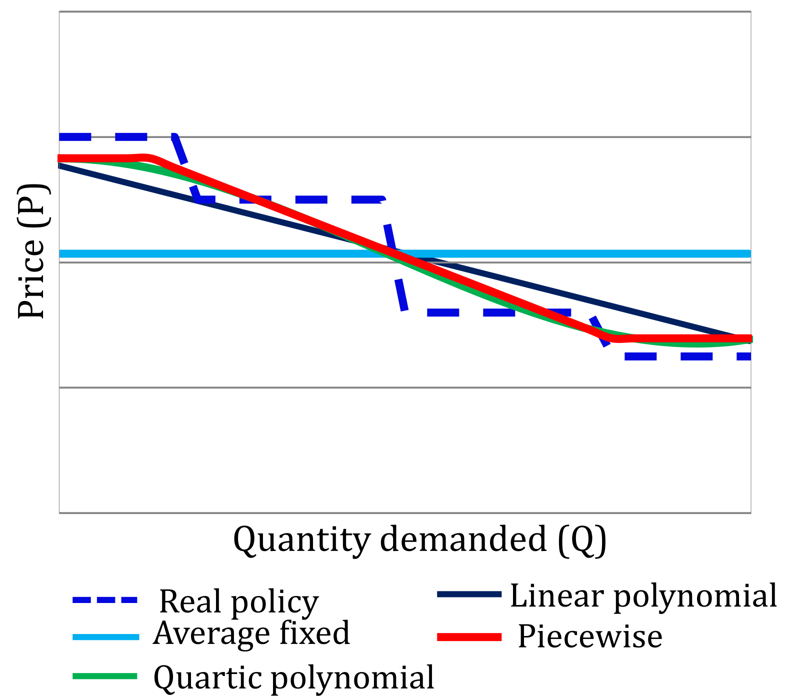


Optimal integration- Results

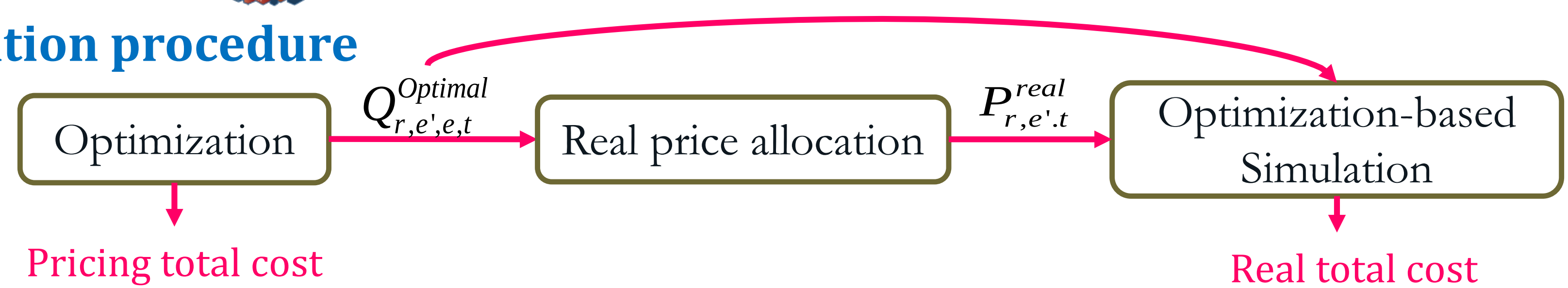
Case study: Global coordinated SC



Pricing models

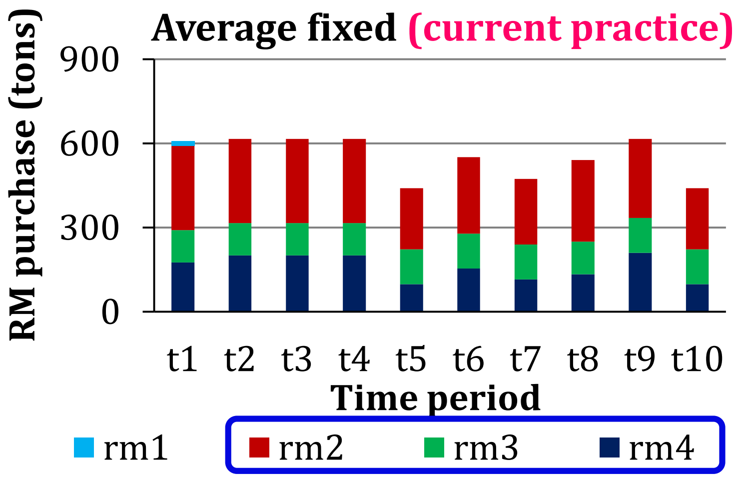


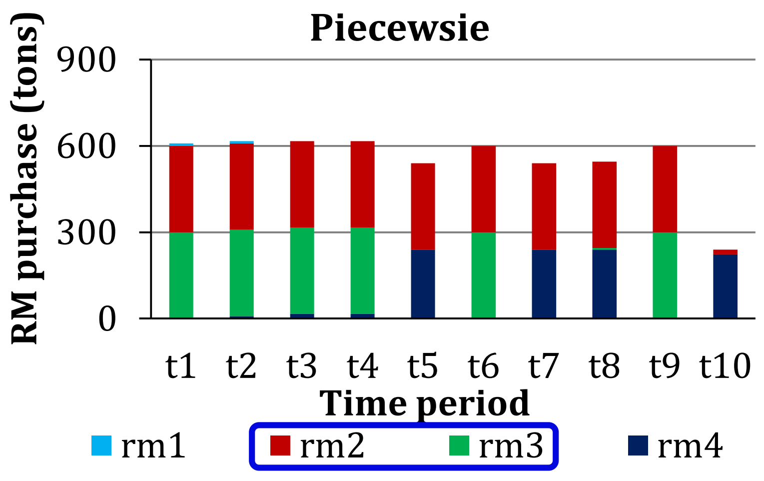
Solution procedure

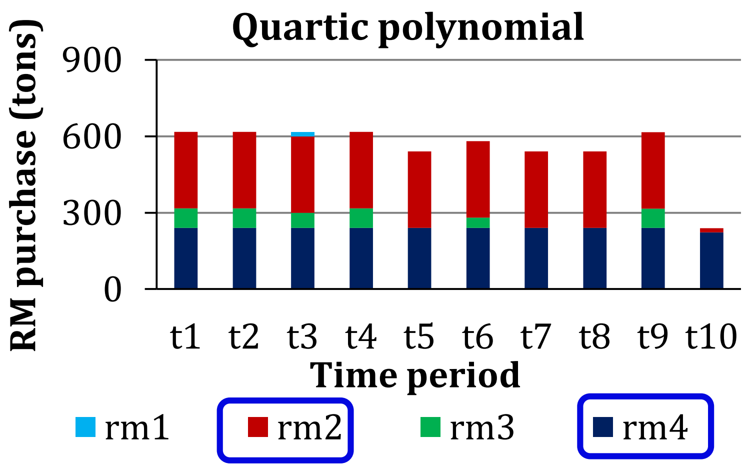


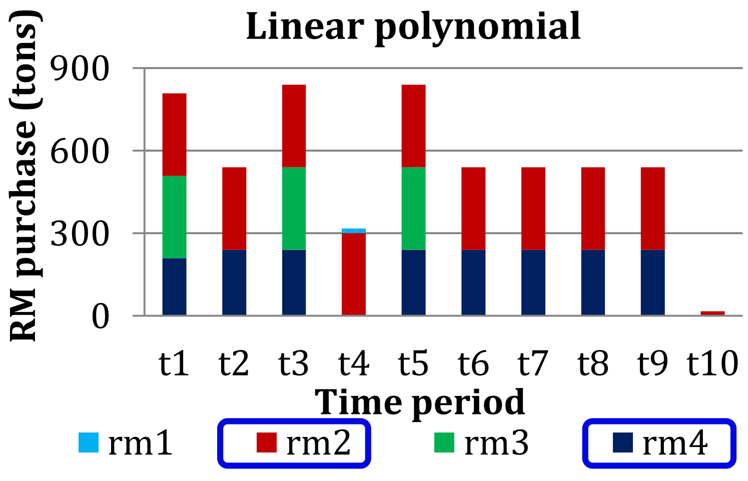
Results- Tactical decisions

Polystyrene production SC



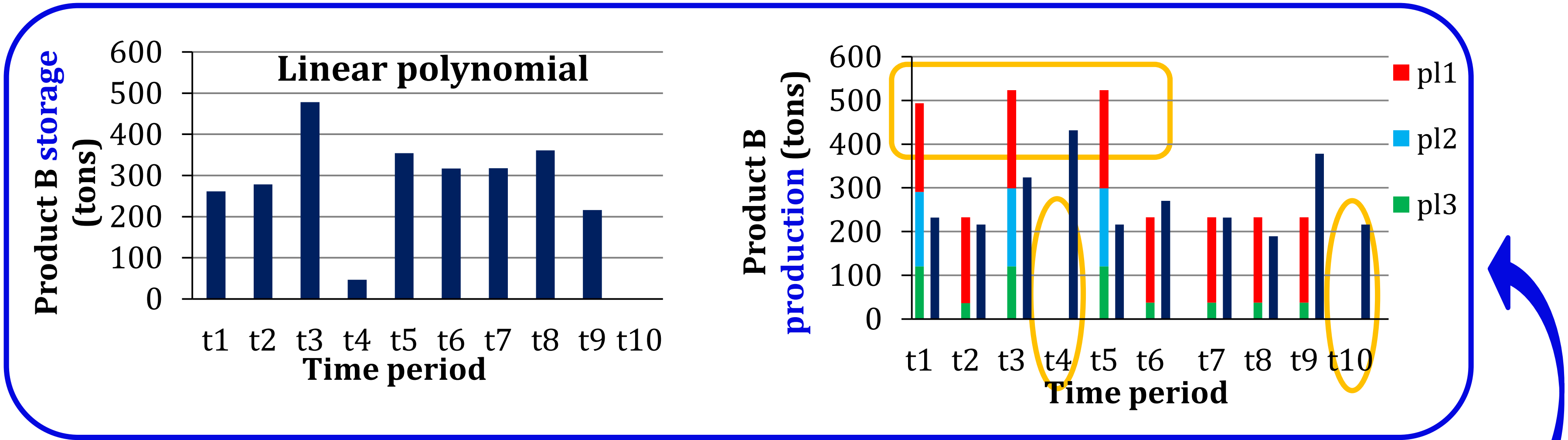




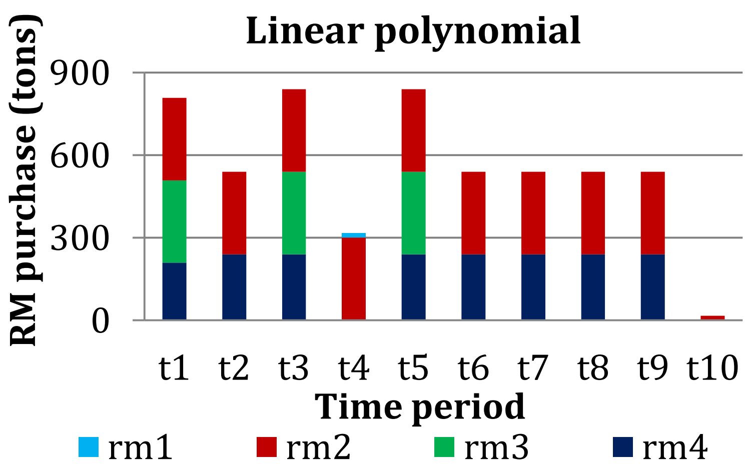


Results- Pricing models optimization

Polystyrene manufacturing SC



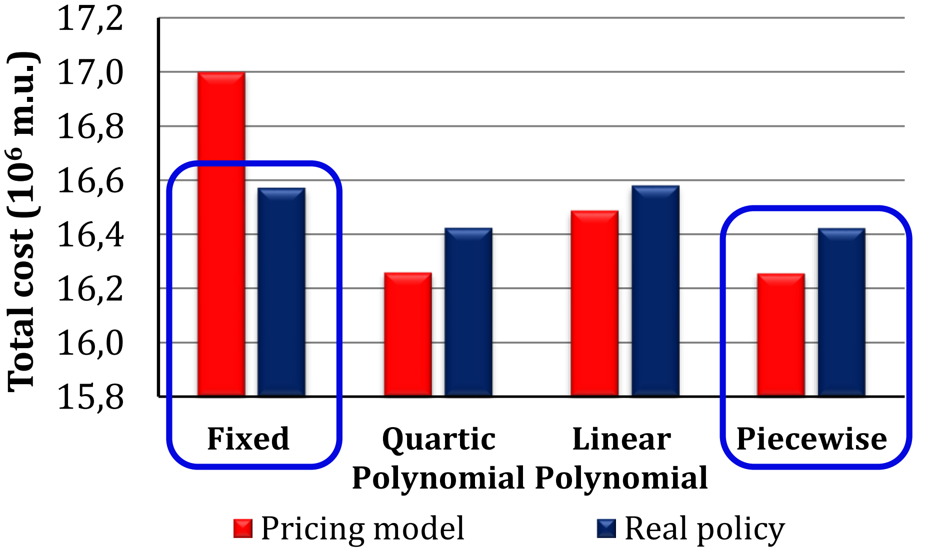
Using **discounting pricing** drives the decision-maker to purchase **higher RM amounts** in order to obtain lower prices. This leads to produce **extra products** to be **stored** for later distribution.



Results- Optimization-based simulation

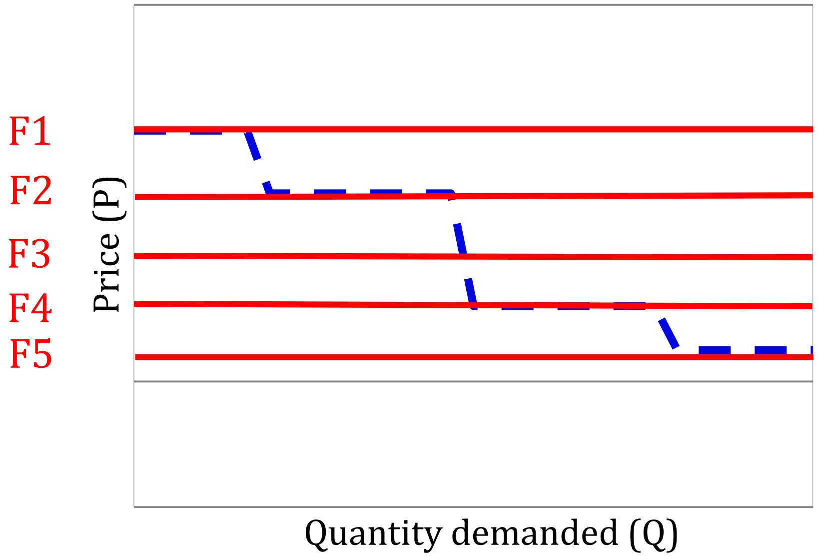
Economic analysis

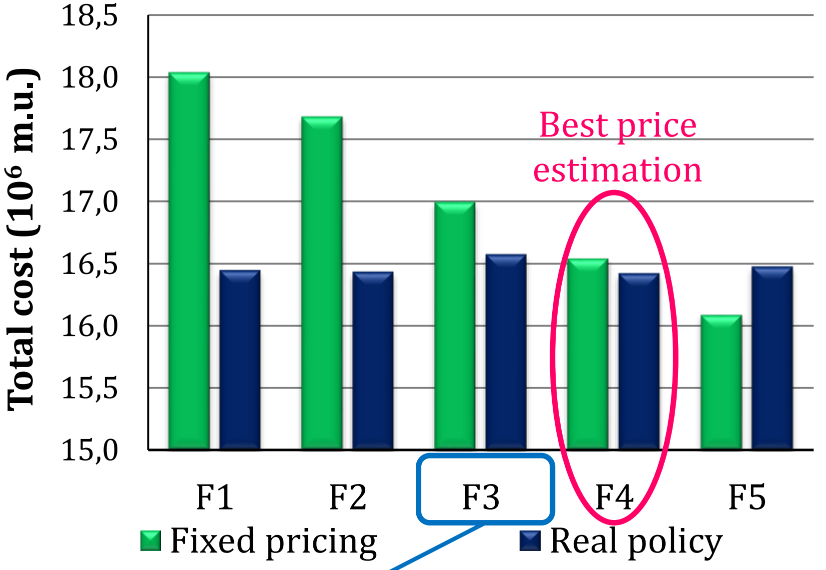
- Piecewise ➔ best approximation
  ➔ lowest RM cost
- Average fixed (current practice)
  ➔ Worst approximation
  ➔ highest RM cost



							Total Cost ($x10^6$ m.u)	
	Model	Single equations	Single variables	Discrete variables	Solver	CPU (sec)	Pricing model	Real policy
Average fixed	LP	2,752	4,991	-	CEPLX	0.05	**17.00**	**16.57**
Quartic polynomial	NLP	2,952	5,191	-	CONOPT	0.13	16.26	16.42
Linear polynomial	NLP	2,952	5,191	-	CONOPT	0.11	16.49	16.57
Piecewise	MINLP	3,336	5,495	240	DICOPT	5.80	**16.25**	**16.42**

Results: Economic analysis





The traditional **average** approximation is **not recommended**

Conclusions

This work constitutes an **advance in PSE** by proposing **novel flexible decision-support tools** enabling **all possible links** with all possible **participants**

- **Cooperative-base global coordination**
  - Improvement of the global **performance**.
  - **Less consumption** of resources.

- **Pricing as collaborative tool**
  - 3^{rd} parties control their **financial channels**.
  - **Discounting** pricing enhances **competence**.
  - **Average** approximation is **not recommended**.

Don’t lose sight when optimizing individual objectives

Future work

This work opens new opportunities for **future research** in the line of multi enterprise-wide coordination (M-EWC) of **multi-participant** SCs.

- ❖ Decentralized optimization.
- ❖ Competence between main actors.
- ❖ Quality of the data.
- ❖ Environmental and social issues.
- ❖ Complex multi-objective models
- ❖ New sources of uncertainty
- ❖ Risk-sharing.
- ❖ New algorithms to solve complex models

References

Journals articles

- Zamarripa, M.; Hjaila, K.; Silvente, J.; Espuña, A. Tactical Management for Coordinated Multi-echelons Supply Chains. Computers & Chemical Engineering, 66: 110-123 (2014).
- Hjaila, K.; Laínez, J., Puigjaner, L.; Espuña, A. Decentralized Manufacturing Supply Chains Coordination under Uncertain Competitiveness. Procedia Engineering, 132: 942-949 (2015).
- Hjaila, K.; Laínez, J.; Zamarripa, M.; Puigjaner, L.; Espuña, A. Optimal integration of third-parties in a coordinated supply chain management environment. Computers & Chemical Engineering, 86: 48-61 (2016).
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Scenario-based dynamic negotiation for the coordination of multi-enterprise supply chains under uncertainty. Computers & Chemical Engineering, 91, 445–470(2016).
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Integrated Game-Theory Modelling for Multi Enterprise-Wide Coordination and Collaboration under Uncertain Competitive Environment. Computers & Chemical Engineering, accepted with comments.

Conference proceeding articles

- Zamarripa, M.; Hjaila, K.; Silvente, J.; Espuña, A. Simplified model for integrated Supply Chains Planning. *Computer Aided Chemical Engineering*, 32:547-552 (2013).
- Zamarripa, M.; Hjaila, K.; Cóccola, M.; Silvente, J.; Méndez, C.; Espuña, A. Knowledge-based approach for the integration of the planning and scheduling decision making levels. *Chem Eng. Trans*, 32:1339-1344 (2013).
- Hjaila, K.; Zamarripa, M.; Espuña, A. Application of pricing policies for coordinated management of supply chains. *Computer Aided Chemical Engineering*, 33:475-480 (2014).
- Hjaila, K.; Puigjaner, L.; Espuña, A. Scenario-based price negotiations vs. game theory in the optimization of coordinated supply chains. *Computer Aided Chemical Engineering*, 37:1859-1864 2015.
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Management coordination for superstructures of decentralized supply chains under un- certainty. *Operations Research Proceedings (*2015).

Congresses

- Zamarripa, M.; Hjaila, K.; Silvente, J.; Espuña, A. Simplified model for integrated Supply Chains Planning. *ESCAPE-23*, 9-12 June 2013, Lappeenranta.

References

- Zamarripa, M.; Cóccola, M.; Hjaila, K.; Silvente, J.; Méndez, C.; Espuña, A. Knowledge-based approach for the integration of the planning and scheduling decision making levels. *ICheaP-11*, 2-5 June 2013- Milan.
- Hjaila, K.; Zamarripa, M.; Shokry, A; Espuña, A. Application of pricing policies for coordinated management of supply chains. *ESCAPE-24*, 15-18 June 2014- Budapest.
- Hjaila, K.; Zamarripa, M.; Espuña, A. Analysis of the role of price negotiations and uncertainty in the optimization of coordinated supply chains. *IFORS-20*, 13-18 July 2014 - Barcelona.
- Shokry, A.; Hjaila, K.; Espuña, A. Adaptative evolutionary optimization of complex processes using a kriging based genetic algorithm. *MCCE13*, 30 Sep- 3 Oct 2014- Barcelona.
- Hjaila, K.; Puigjaner, L.; Espuña, A. Negotiations Provider-Client for Sup- ply Chains Coordination under Competitiveness. *CAPE-Forum 2015*, 27-29 April 2015- Paderborn.
- Hjaila, K.; Puigjaner, L.; Espuña, A. Scenario-based price negotiations vs. game theory in the optimization of coordinated supply chains. *PSE2015/ESCAPE25*, 31 May-4 June 2015, Copenhagen.
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Non-cooperative games for the optimization of multi-enterprise supply chains under un- certainty. *AIChE Annual Meeting-2015*, 8-13 November 2015, Salt Lake City.
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Application of game theory to the optimization of decentralized supply chains under uncertainty. *ECCE10*, 7 Sep- 01 Oct 2015- Nice.
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Game-based modeling for the optimal management of decentralized supply chains un- der competitiveness. *EURO27*, 12 - 15 July 2015, Glasgow.
- Hjaila, K.; Puigjaner, L.; Espuña, A. Tactical Management of Decentralized Supply Chains Superstructures under Uncertainty. *EURO27*, 12 - 15 July 2015, Glasgow.
- Hjaila, K.; Puigjaner, L.; Espuña, A. Decentralized Manufacturing Supply Chains Coordination under Uncertain Competitiveness. *MESIC 2015*, 22-24 July 2015, Barcelona.
- Hjaila, K.; Laínez, J.; Puigjaner, L.; Espuña, A. Management Coordination for Superstructures of Decentralized Large Scale Supply Chains under Uncertainty. *OR2015*, 1-4 September 2015. Vienna.
- Hjaila, K.; Puigjaner, L.; Espuña, A. Optimal Operation of Decentralized Multi-Enterprise Multi-Period Supply Chains under Uncertainty. *AIChE Annual Meeting-2016*, 13-18 November. San Francisco.

Proactive Management of Uncertainty in Process and Supply Chain Planning

Extending the management horizons in front of the integration paradox

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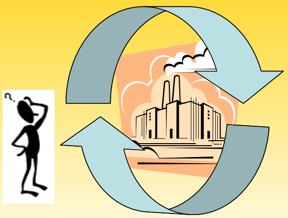
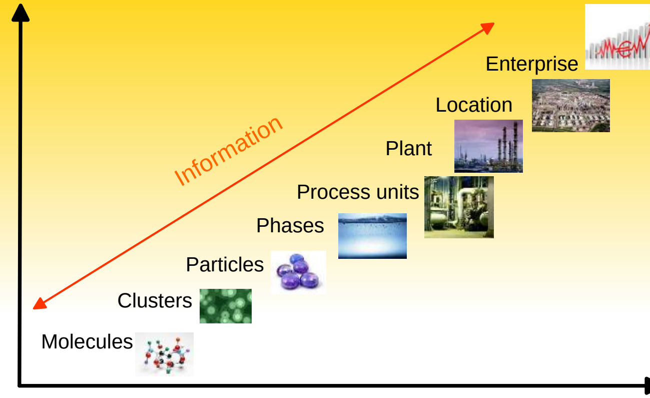
Safety and Environmental Technology Group
Carnegie Mellon University
Barcelona - Pittsburgh, March 8th, 2018

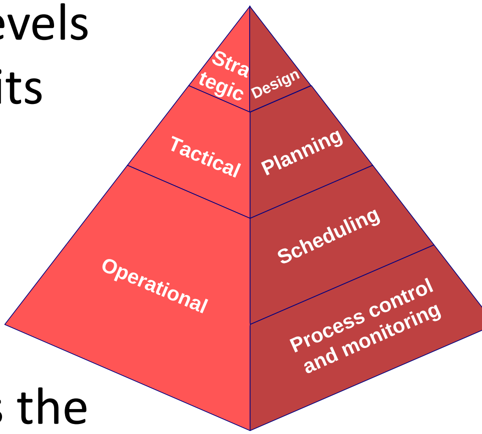
SC Management





Classical approach: hierarchical - sequential - pyramidal

- Each decision level imposes decisions / constraints to lower levels
- Each decision level maintain its own objectives and manages its own control variables
- Current standards: same approach
  - Purdue Model → ISA 95 (ISO 62264) + ISA 88 (ISO 61512)



BUT

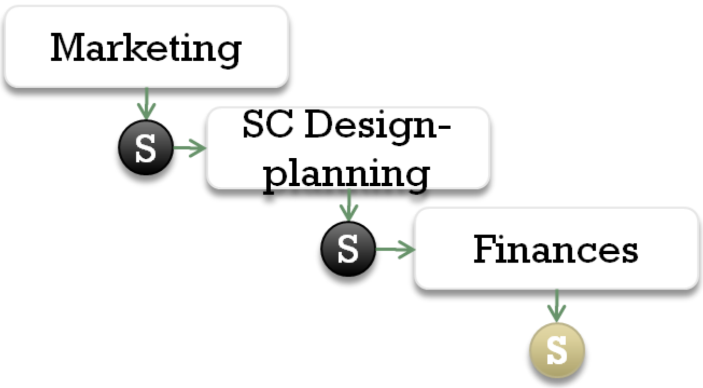
- The optimal solutions of the individual levels, are the same as the optimal solution of the individual problems?

➔ Alternative: Integration into a Monolithic structure

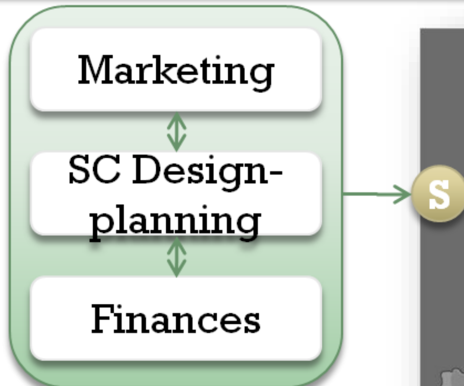
Integration benefits: Motivating example

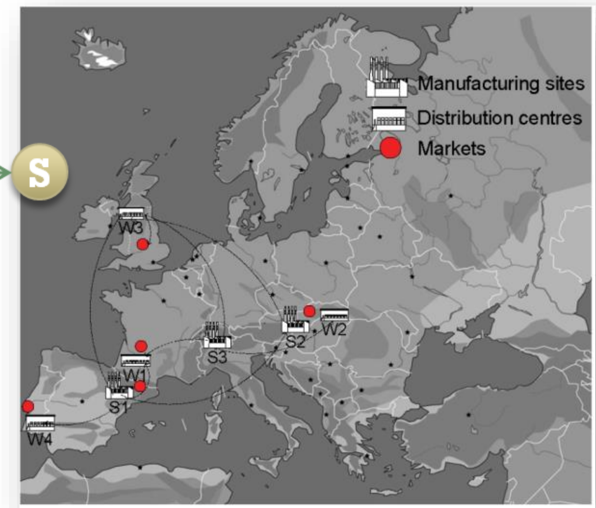
(Laínez *et al.*, C&CE, 2009)

Sequential approach



Integrated approach



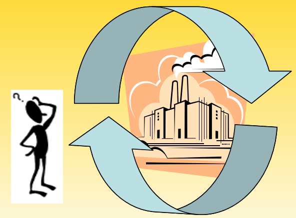


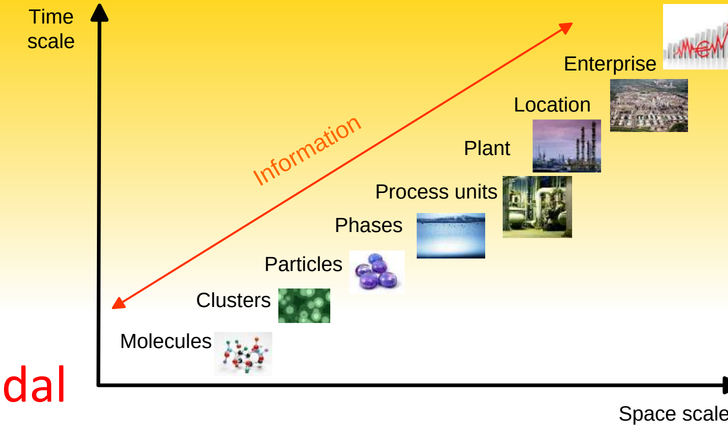
Approach	Revenues	Advertising expenditures	Net revenues	Corporate value	Investment in capacity
Sequential	522.32×10^6	86.11×10^6	436.21×10^6	84.35×10^6	79.77×10^6
Integrated	512.94×10^6	85.15×10^6	427.79×10^6	123.93×10^6	43.42×10^6

-2% (Net revenues)

+47% (Corporate value)

SC Management





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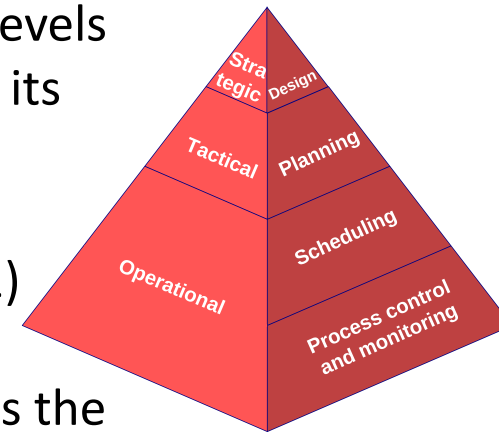


BUT

- The optimal sol e individual levels, are the same as the optimal sc e individual problems?

The integration paradox

→ Alterna e: Integration into a Monolithic structure

BUT Complex resulting mathematical problem (large and complex)

THEN: Which is the added value? (vs. simplifying assumptions and uncertainty)

Issues to solve the integration paradox

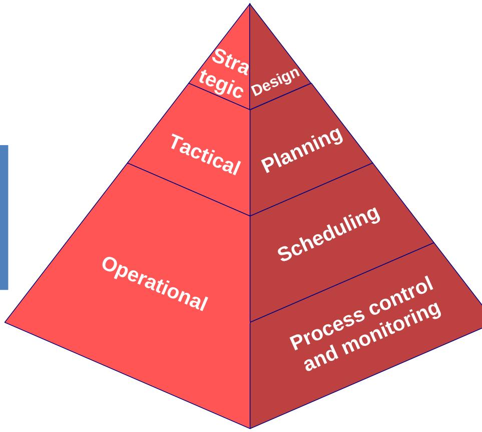
(Zondervan and de Haan, 23rd ECMS, 2009)

- Structural differences in the models currently used at each hierarchical levels (V
- Lack of a proper Info … een levels (Stephanopoulos & …
- Lack of a reliable way … formation (S… obrys & White, 2002)
- … ble … opt … 200…

Open Issues

Vertical Integration | Uncertainty Management | Market globalization (third parties) | Multi-objective analysis

?



- Is there a common manageme…
  - Abstract objective: … the current flexibility
  - Common metri… … best?)
- Which elemen… manager (DOFs) ? In which range?
  - Abstract … uous variables (process management, production manageme… teger variables (sequences, logic decisions, …)
- Which is the work… scenario?
  - Dynamic situation → Unexpected events/incidences at all decision making levels
  - Competition

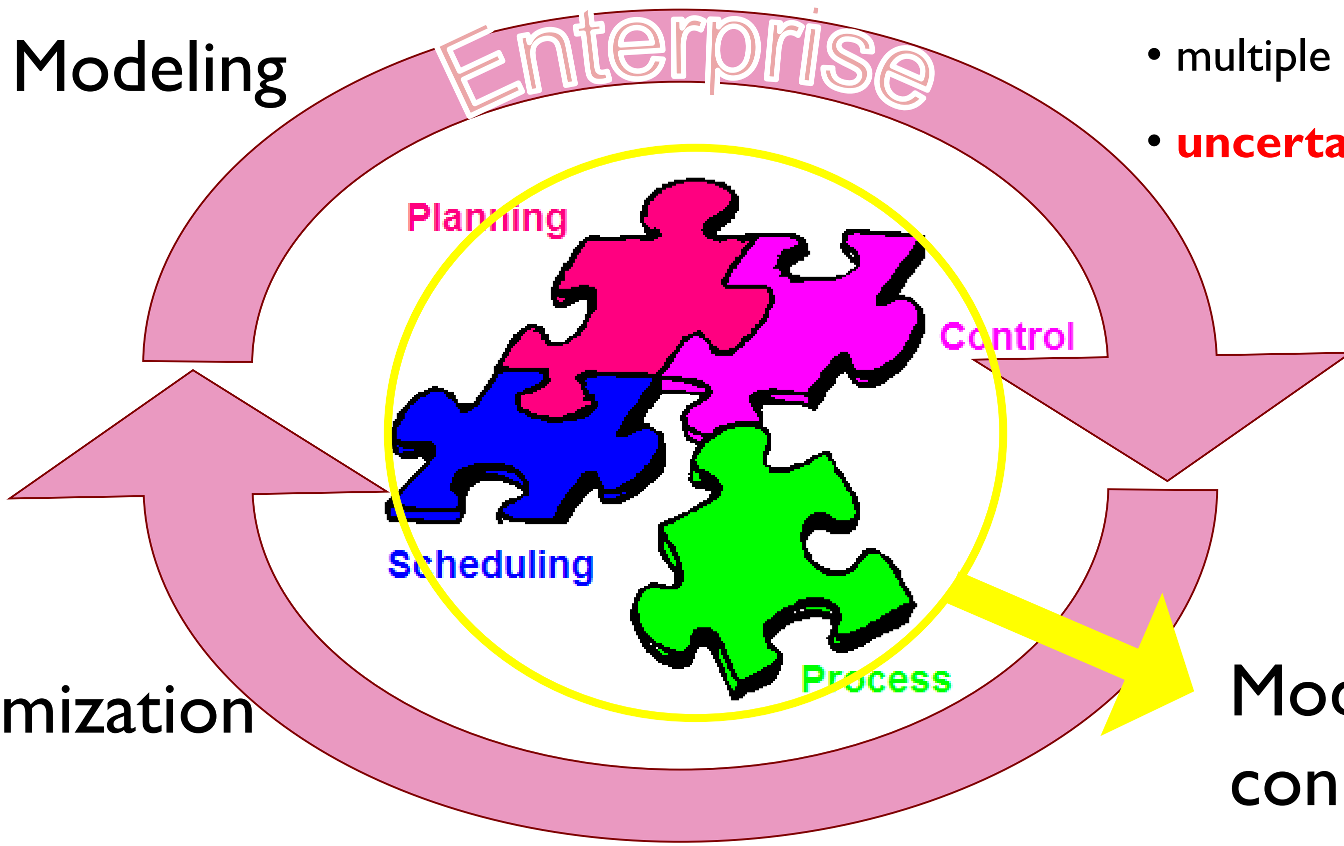
- Equivalent approa…
- Equivalent formulation

Process Engineering

Modeling

Decision making

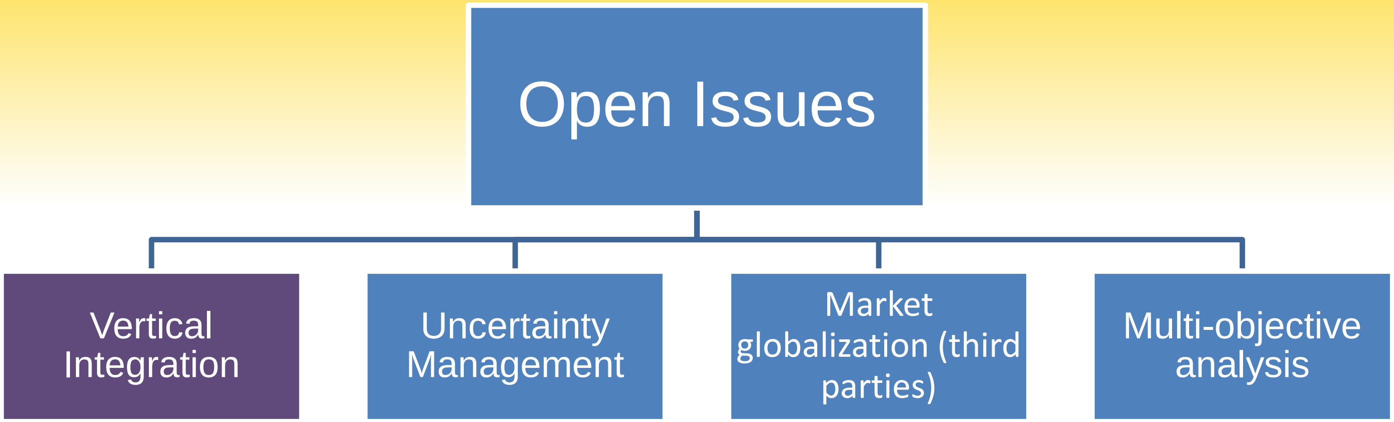
- multiple objectives
- **uncertainty**



Optimization

Model connections

Deviations from ideal process (model)



Open issues

- Enhance the process operation and flexibility by including the operational knowledge at the design DM problem.
- Integration of planning, scheduling and control at the plant level.
- Ensure consistency, feasibility and optimality across models that are applied over large changes in time scales (years, months, down to days and seconds).

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Open Issues

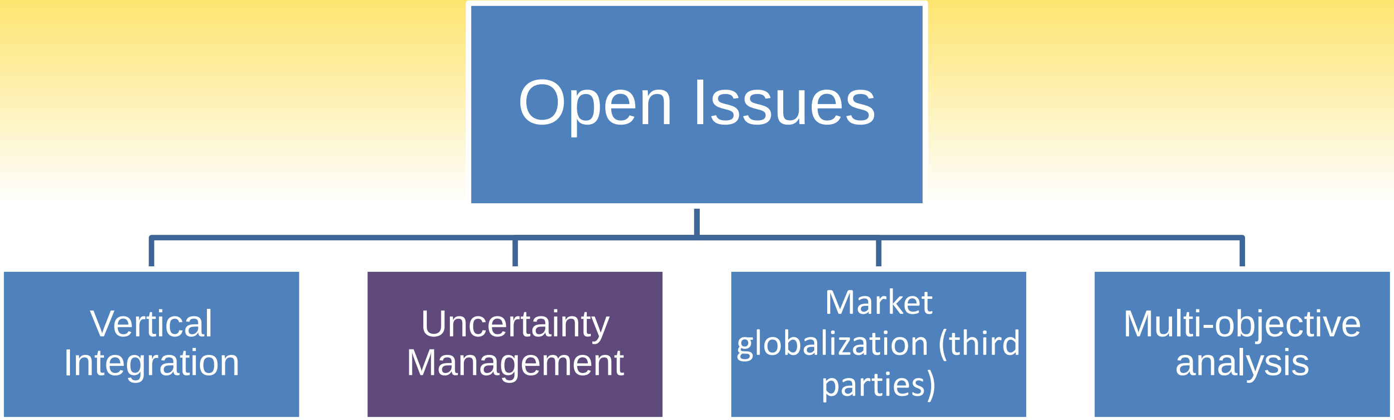
- Vertical Integration
- Uncertainty Management
- Market globalization (third parties)
- Multi-objective analysis

Tactical DM under uncertainty:

- Availability of production resources
- Raw materials supply
- Operating parameters (lead times, transport times, etc.)
- Market scenario (**demand**, prices, delivery requirements, etc.)

Tools:

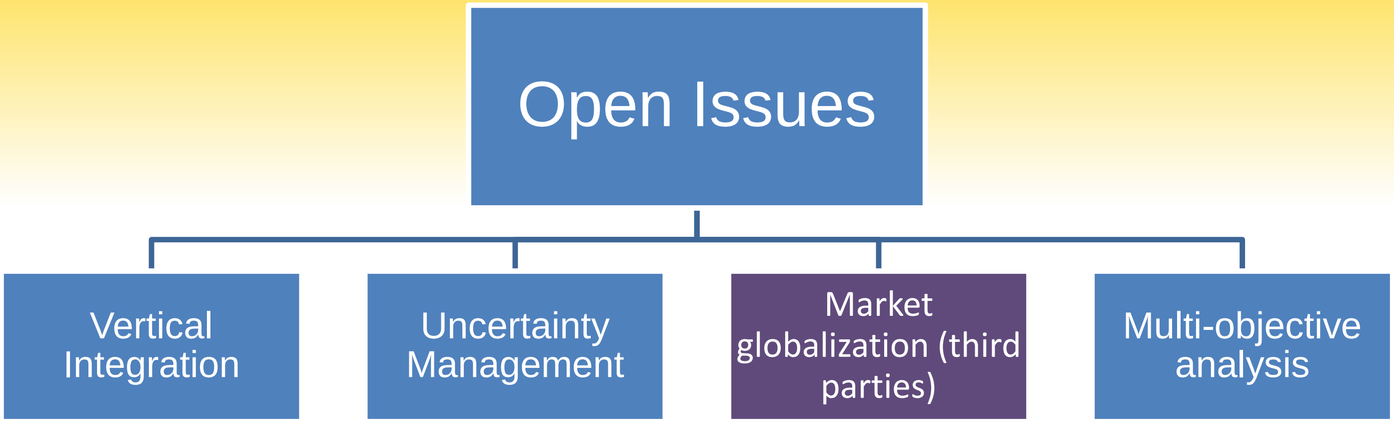
- **Model Predictive Control** (Bose and Penky, 2000),
- **Multi-Parametric Programming** (Wellons and Reklaitis, 1989; Dua *et al.*, 2009)
- **Fuzzy Linear Programming** (Peidro *et al.*, 2010)
- **Stochastic Programming** (Gupta and Maranas, 2003; You and Grossmann, 2010; Amaro and Barbosa-Póvoa, 2009; Baghalian, 2013; Klibi and Martel, 2012).



Proposed approach

- To extend the scope of the SCM approaches under uncertainty by considering new sources of uncertainty
  - Competitors behavior (Exogenous source of the demand uncertainty), interaction with other SCs, etc.

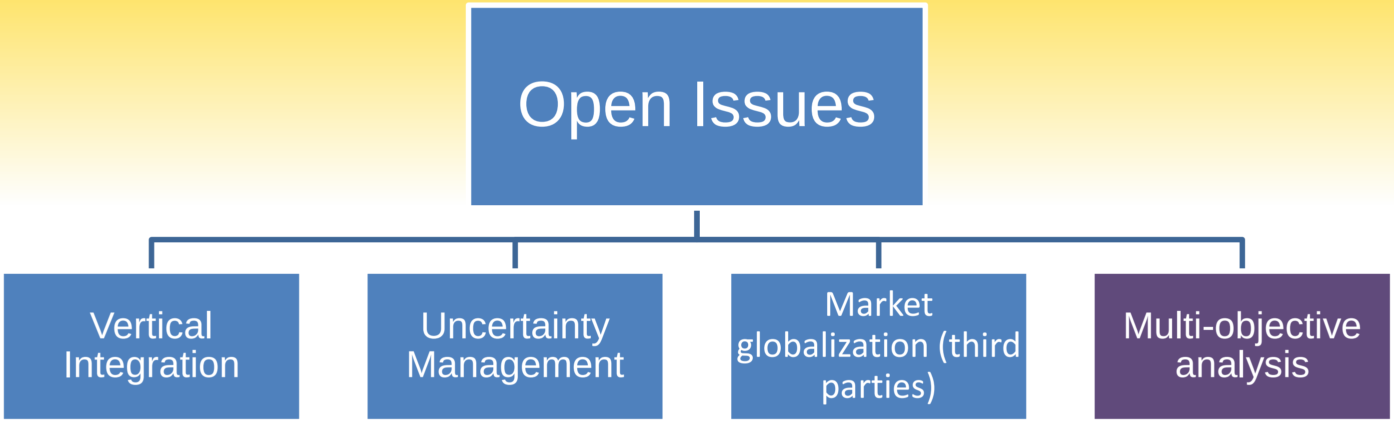
- To develop Reactive and Proactive approaches to manage this new uncertainty source



- It is necessary to interact with the competitors
  - (cooperative and competitive scenarios)

- Cooperative
  - Vertical integration or coordinated models include cooperation among SC entities.
  - Buyer and seller negotiation lead to changes in the contracts.

- Competitive
  - Nash and Stackelberg Equilibriums to fix the price between seller and buyer.

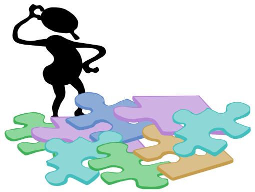


Change the Multi-Objective Optimization paradigm:

- Move from the typical MOO approach that looks for several objectives (contradictory) →
- Take into account Objectives from different entities
  - **SC producers (economic)**
  - **Customers (Delivery time, quality, etc.)**

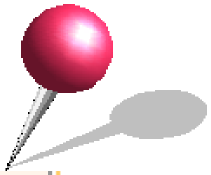
Present and prospective analysis

- General models and solution methodology for decision-making under uncertainty. Extended scope (multilevel).
- Computational requirements to solve practical problems.
- Formalism(s) for robustness and flexibility; reactive view of operational uncertainties.
- Integrated production and transport scheduling.
- To integrate third parties / new objectives.



Critical points

- Computational requirements
- Multiple sources of uncertainty
- Multiple and conflicting objectives



Present and prospective analysis:

How decision making robustness can be improved? Which are the benefits?

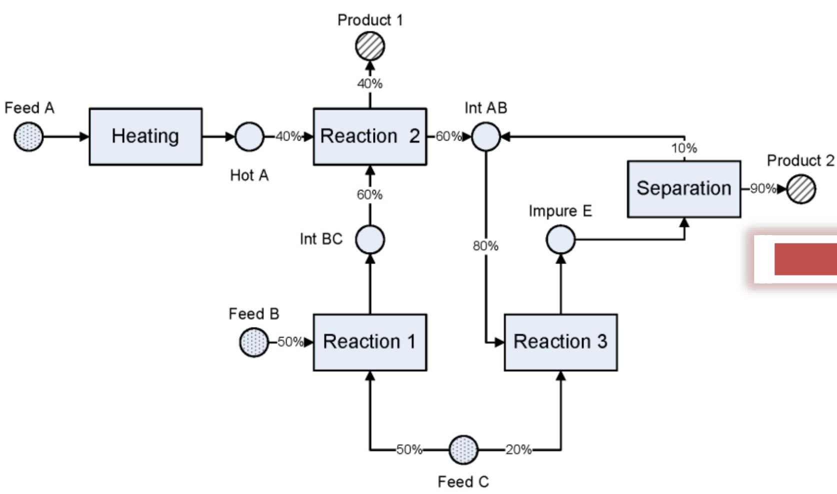
Development of a general decision-support framework for operational analysis of process systems under uncertainty, to further exploit their flexibility, taking advantage of the uncertainty characterization for efficient and robust predictive (proactive) decision-making.

- Study of different sources of uncertainty and their effects at tactical / operational levels.
- Evaluation of robustness measures.
  - ✓ Formalism(s) for production to distribution robustness.
- Equation-based and procedure-oriented approaches.
- Sampling techniques.
- Extensions to the integrated / multilevel view

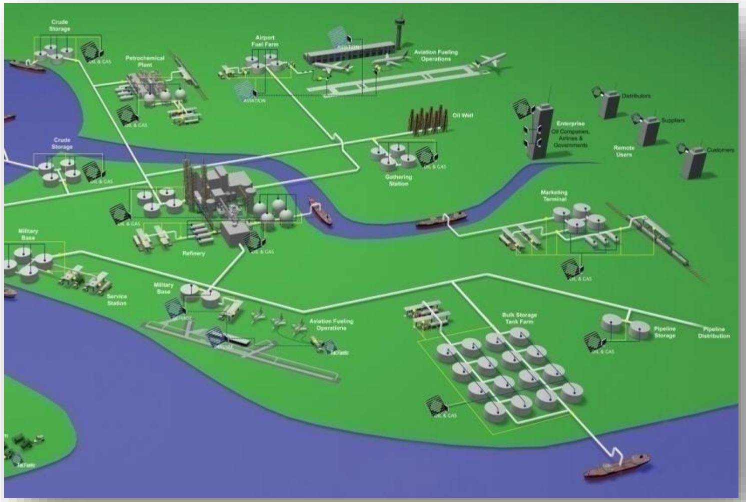
Proposed Methodology (general view)

- To extend the same information model / information links to different contexts
- To apply equivalent management / decision making procedures

- STN Representation (Kondili et al., 1993)



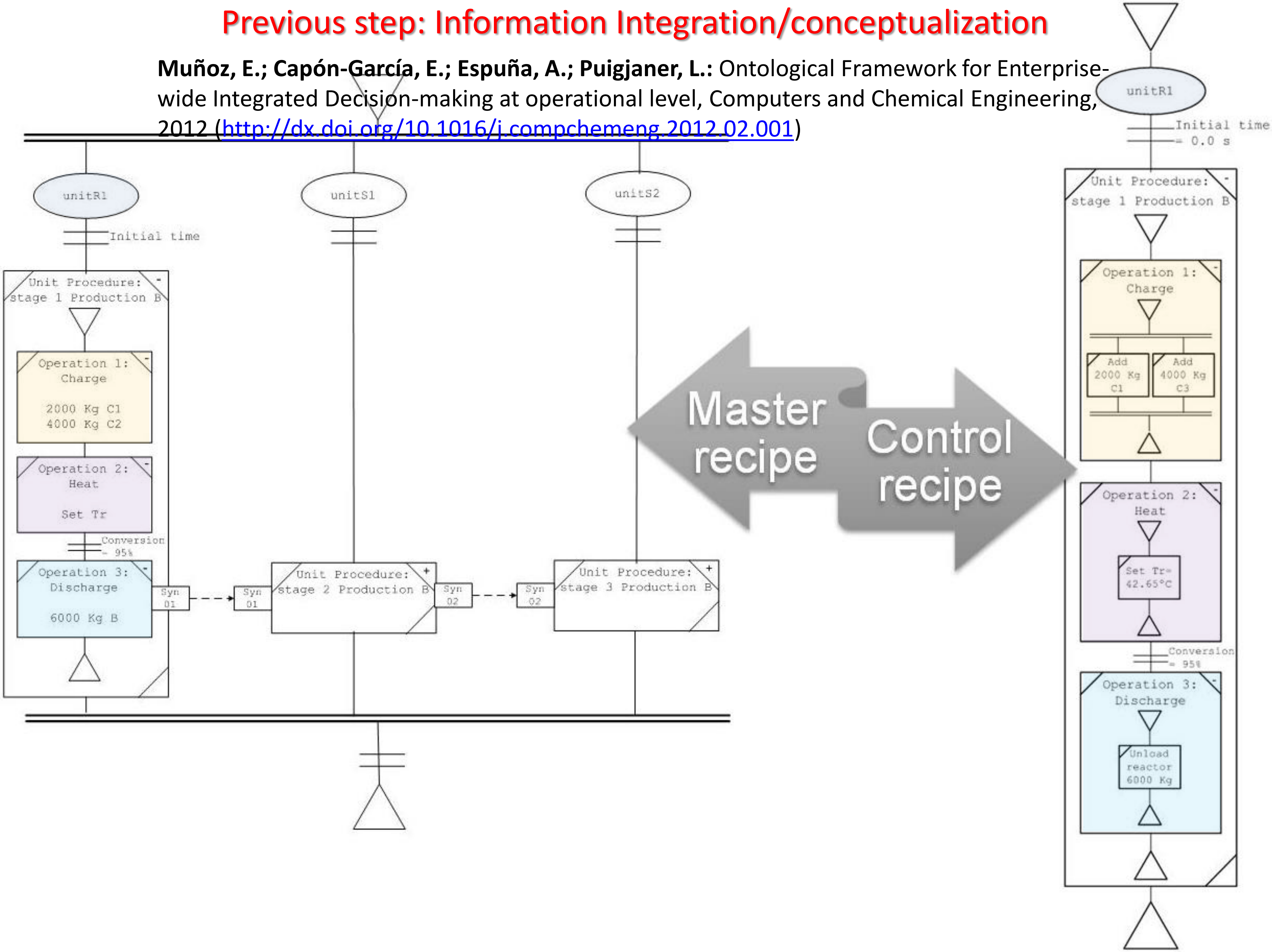
- Supply chain context



  - Different plants / production centers
  - Transport and distribution activities

Previous step: Information Integration/conceptualization

Muñoz, E.; Capón-García, E.; Espuña, A.; Puigjaner, L.: Ontological Framework for Enterprise-wide Integrated Decision-making at operational level, Computers and Chemical Engineering, 2012 (http://dx.doi.org/10.1016/j.compchemeng.2012.02.001)



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