Negotiations Provider-Client for Supply Chains Coordination under Competitiveness

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Abstract

Current tactical models of Supply Chains (SC) associate the conflicts among independent SCs with the uncertain behaviour of external echelons (third parties). Although the trend now arises to solve these conflicts using multi-objective optimization and game theory, typical analytical models do not consider the benefits of uncertainty reduction obtained when a supply/demand contract is agreed, which can be modelled as the probability of acceptance of solutions with reduced benefits, where lies precisely the novelty of this work. Accordingly, this work proposes a win-win scenario-based negotiation approach, for the case of decentralized multi-site and multi-product SCs in a highly competitive environment. Different price scenarios, offered by the leader SC, are analyzed for the negotiation item, resulting in different MINLP tactical models, which are illustrated using a case study that coordinates different suppliers' SCs with an industrial production/distribution SC in a global scenario. The negotiation scenario resulting from maximizing each SC profit proves to be the most adequate, leading to higher global profits.

Keywords

Tactical management, coordination, negotiations, probability of acceptance, uncertainty, Monte-Carlo.

Background

The competitiveness among chemical industries shifts the interest of Process Systems Engineering (PSE) towards SCs coordination based on individual and global benefits. Many works have been carried out to highlight the coordination among several SCs, such as the integration of different SCM levels in which an enterprise-wide cross-functional coordination model is proposed by integrating both strategic and tactical levels [1]; or the coordination of suppliers and production SCs at the tactical level using different pricing models for centralized SCs [2]. But, these works support decisions based on the objectives of one centralized organization, usually optimizing its benefits, disregarding the individual goals of the independent SCs, especially when dealing with decentralized SCs, and thus conflicts may arise.

Solving these conflicts from a negotiation perspective has been studied through multi-objective optimization and Game Theory. For instance, negotiations through "revenue sharing" based on Stackelberg game for one manufacturer and many competing retailers [3]; or through developing a bi-level MINLP design and planning model under the leading role of the manufacturer [4]. Most of the negotiation mechanisms through Game Theory at the tactical level focus on the competitiveness among the retailers disregarding the supplier's competitive behavior. Furthermore, the aforementioned approaches are based on single leadership, without considering uncertainty reduction costs when the negotiating partners arrive to an agreement, leading to insufficient coordination. Price negotiations as a way to reach a coordination agreement has been studied in the literature; as a qualitative methodology [5], or based on the "timing" between producer and customer, such as waiting to sell or to buy under the uncertain buyer's revenue and seller's cost [6].

Accordingly, this work aims to help solving these conflicts by establishing the best conditions for the coordination contract through quantitative negotiations built on win-to-win principles by considering the aforementioned issues in one single approach. A scenario-based negotiation approach will be developed taking into consideration the individual and global profits based on independent and dependent SCs optimization at the tactical level. The decisions provided are the raw materials (RM) acquisition, intermediate product price/quantity, production, inventory, and distribution levels under the objective function of maximizing the profit (individual/global).

Methods

Assume that there are two completely independent SCs with their own independent suppliers and markets (Figure 1). SC2 as a leader partner decides to improve its benefits by buying internal product/s from SC1 (follower); the negotiation item is thus the product's supply/demand. A scenario-based negotiation approach is developed; the methodological framework (Figure 1) consists on analyzing different price scenarios for the negotiation item offered by the leader SC: The negotiation procedure is divided into two main steps: 1) Negotiation scenarios, and 2) Coordination agreement. The first step aims to find out the best negotiation scenario to be used for the second step.

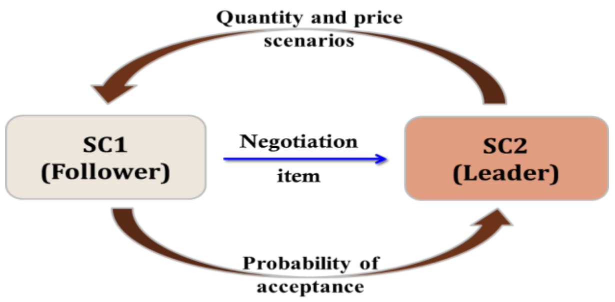

Figure 1- Negotiation methodology

1) Negotiation scenarios:

Pre-Negotiation Scenario: Both negotiating partners optimize their SCs profits separately, without considering the internal products (without coordination).

Negotiation Scenario I) "Individual objectives-based negotiation":

- The leader offers the follower SC a set of contract prices for the negotiation item (internal product) ensuing from maximizing its SC profit, resulting in a set of internal product quantities each planning time period.
- Based on these quantities and prices, the follower maximizes its SC profit.
- A set of total Profits are obtained (SC1 profit + SC2 profit).

Negotiation Scenario II) "Global objective-based negotiation": For each price and quantity scenarios, both negotiating partners are united in one global model to maximize the global SC profit, resulting in a complex objective function (SC1 profit & SC2 profit).

After analyzing the three scenarios, the most profitable (with the highest total profit) is considered for preparing the coordination agreement (step 2).

2) Coordination agreement

After selecting the most adequate negotiation scenario, the leader SC expects a set of apparent prices and the corresponding expected profits,

- The cost of reduction of uncertainty is considered, which is modeled as a probability of acceptance. The probability of acceptance is calculated as the risk associated with the uncertain behavior of the external conditions of the follower SC, as a way to push the negotiation towards win-to-win policy. To do so, and for each contract price offer, a set of external risk scenarios (follower SC) are generated using Monte-Carlo method assuming normal distribution, resulting in a set of probability distribution curves.
- The leader SC then calculates its apparent prices in function of the probability of acceptance each scenario; the leader SC model is then optimized for each apparent price, resulting in a set of expected

profits. The apparent price that leads to the most profitable expected profit is settled for the coordination agreement from the leader side.

- The follower then evaluates its SC profit based on the contract price selected by the leader using the corresponding probability distribution curve of the offered contract price.

To apply these negotiation scenarios in a systematic way, a generic mathematical model is developed.

Mathematical model:

A generic MINLP tactical model is developed as a basis for all negotiation scenarios. A set of supply chains (sc1, sc2… SC) is developed with their new subsets linking each SC to its corresponding negotiation partner (follower *F* or leader *L*). The total external demand $xdem_{r,t}$ represents the typical markets' fulfillment of resource r from any echelon as stated by Eq. (1), where M represents the external markets.

$$prod_{r,sc,t} \leq xdem_{r,sc,m,t} \qquad \forall r \in R; m \in M; sc \in SC; t \in T \qquad (1)$$

Eq. (2) represents the negotiation part between the leader and the follower SCs through the internal market demand $idem_{r',sc',t}$ of the negotiation item r', which must be equal to the production levels of r' in the follower SC (*F*).

$$\underset{sc \in L}{idem_{r',sc',t}} = \underset{sc' \in F}{prod_{r',sc',t}} \qquad \forall r' \in R; sc' \in SC; t \in T \qquad (2)$$

The total sales can be calculated by multiplying the price of the final/internal product by the quantity demanded by the external markets *M* and/or the leader SC (Eq. 3). Where $pr_{r',t}$ represents the price of the negotiation item r'

$$SALES_{sc} = \sum_{t \in T} \sum_{r \in R} \sum_{m \in M} pr_{r,m,t} \cdot xdem_{r,sc,m,t} + \sum_{t \in T} \sum_{r' \in R} pr_{r',sc',t} \cdot idem_{r',sc',t} \qquad \forall sc \in SC; sc' \in SC \qquad (3)$$

The SC total cost along the considered planning horizon *T* (RM purchase, transport, storage, and production total costs, respectively) (Eq. 4)

$$COST_{sc} = \sum_{t \in T} (CRM_{sc,t} + CTR_{sc,t} + CST_{sc,t} + CPRD_{sc,t}) \qquad \forall sc \in SC \qquad (4)$$

The objective function corresponds to the maximization of the SC profit (Eq. 5), which is calculated as the difference between the total sales and the total costs. The "abridged" *uncertainty risk* is considered as an uncertainty reduction cost, to be represented with the probability of acceptance $ACprob_{sc'}$ (Eq. 6).

$$PROF_{sc} = SALES_{sc} - COST_{sc} + \textit{ uncertainty risk} \qquad \forall sc \in SC \qquad (5)$$

$$ACprob_{sc'} = No.\ of\ \ scenarios\ of\ \ improved\ profits_{sc'} / Total\ No.\ of\ \ scenarios_{sc'} \qquad \forall sc' \in F \qquad (6)$$

The apparent price $Apr_{r',sc',t}$ is calculated based on the probability of acceptance and the alternative supplier price $xpr_{r,sc',t}$ (Eq. 7)

$$Apr_{r',sc',t} = pr_{r',sc',t}.ACprob_{sc'} + xpr_{r,sc',t}.(1 - ACprob_{sc'}) \quad \forall r \in R; r' \in R; r \notin r'; sc' \in L; t \in T \qquad (7)$$

Application of the negotiation scenarios:

Pre-Negotiation scenario: the internal market demand $idem_{r',sc',t}$ and the *uncertainty risk* will be equal to zero, and therefore, the calculations will end at Eq. (5).

Negotiation Scenario I): in this case, Eq. (2) will be substituted by Eq. (8); the internal market demand $idem_{r',sc',t}$ will be equal to a constant value $E_{r',sc',t}$ each price $pr_{r',sc',t}$ scenario resulted from maximizing the profit of the leader SC,

$$idem_{r',sc',t} = E_{r',sc',t} \qquad \forall r' \in R; sc' \in L; t \in T \qquad (8)$$

Negotiation Scenario II): where the internal market demand $idem_{r',sc',t}$ will be considered as in Eq. (2), and global SC profit model will be optimized for the objective function ($Tprofit$) Eq. (9),

$$Tprofit = \sum_{sc \in SC} PROF_{sc} \quad (9)$$

Case Study:

The proposed approach has been implemented and solved for a case study modified from [7] by decentralizing the entire SC according to the negotiation approach (Figure 2). The negotiating partners are the polystyrene production/distribution SC (as leader), and the Energy generation SC (as follower), while the internal energy represents the negotiation item. One RM supplier of 4 competing biomass suppliers feed 6 energy plants. Four RM competing suppliers provide 3 polystyrene production plants with 4 alternative resources in order to produce two polystyrene products. The final products are stored in 2 DCs and later distributed to the final polystyrene markets. The case study is modelled using the General Algebraic Modeling System GAMS 24.2.3, and the resulting MINLP tactical models have been solved for 6 time periods; 1000 working hours each, using Global mixed-integer quadratic optimizer (GloMIQO). To obtain the probability of acceptance of the Energy SC, and the probability distribution curves, the model has been solved, each price scenario, for 500 generated scenarios using Monte-Carlo method (assuming normal distribution).

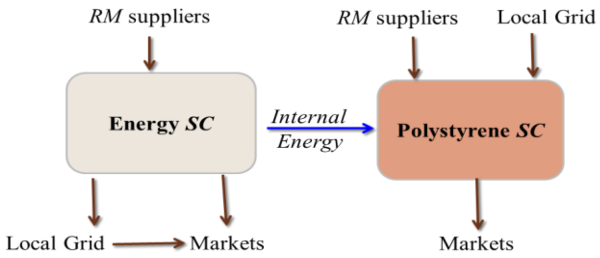

Figure 2- Negotiating SCs partners

Results and discussion

The individual and global profits based on the negotiation scenarios were obtained. Figure 3 shows the resulting total profits vs the negotiation item (internal energy) contract price. The violet line represents the total profit ensuing from the pre-negotiation scenario. The negotiation starts when total profits exceed this line, otherwise, coordination is not necessary. It is noticed that the individual objectives-based negotiation scenario (I) proves to be a better negotiation approach than scenario (II), as it leads to higher total profits in most of the contract price scenarios, with the highest amount of 17.49 M€ at the contract price 0.18 €/kWh, with a difference of 8.6% and 3.5% comparing with the pre-negotiation and scenario (II). Furthermore, the model statistics shows that scenario (I) provides solutions in less computational times (CPU 11.8 sec) compared with 15.6 sec and 31.6 sec needed for the pre-negotiation and scenario (II) approaches.

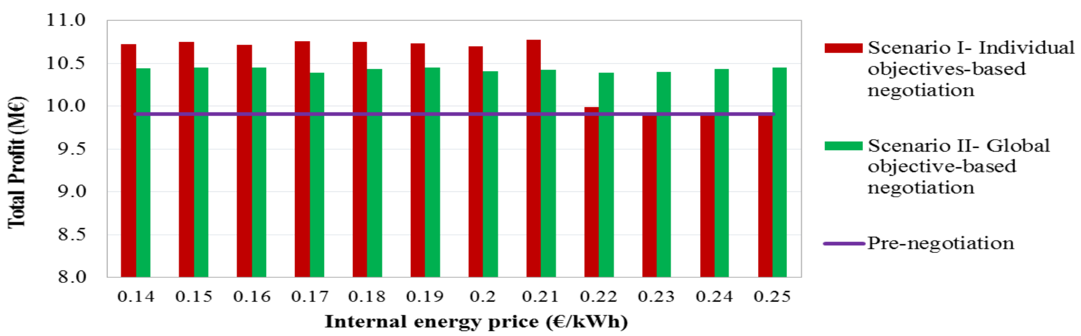

Figure 3- Negotiation scenarios total profits

To analyze the negotiation scenario (I) (before the agreement), Figure 4 shows the economic decisions arising from the negotiating contract prices. Figure 4a represents the energy SC Costs and the breakdown of the total sales. It is worth noticing that the highest energy SC profit corresponds to the contract price (0.21 €/kWh) with 3.25 M€, while the polystyrene SC profit reaches the lowest (7.53 M€) before returning to their pre-negotiation status (Energy SC profit: 2.44M€; Polystyrene SC profit: 7.44 M€) at prices scenarios (0.23-0.25€/kWh), as the polystyrene SC prefers to purchase energy from the local Grid at lower prices (0.2 - 0.22 €/kWh). Here, it can be noticed the competitiveness role in the negotiations, leading to exclude the contract price scenarios (0.23-0.25 €/kWh) from the next negotiation step (coordination agreement).

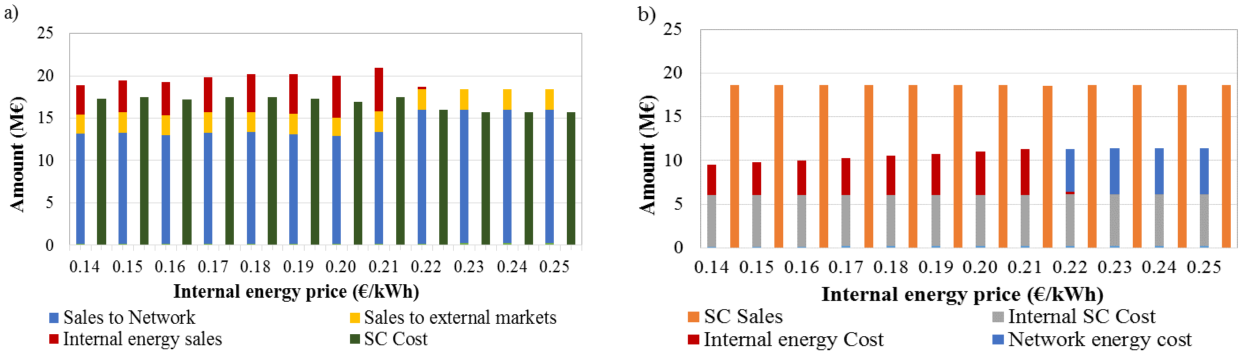

Figure 4- Scenario I analysis- economic decisions profile
a) Energy SC b) Polystyrene SC

The probability of acceptance is calculated each contract energy price, based on 500 generated risk scenarios for the external energy prices of the Energy SC, assuming normal distribution. Figure 5 shows the contract and expected Polystyrene SC profit vs the probability of acceptance. It can be noticed that the highest expected Polystyrene SC profit (7.88M€) is at contract price (0.15 €/kWh) (Table 1), which is 14% less than the contract Polystyrene profit (8.98M€) at the same contract price. It is expected that the probability of acceptance curve increases as the contract price increases; but at contract price (0.22 €/kWh), the polystyrene SC decides to buy higher amounts of energy from the local Grid network (Table 1), resulting in the sudden decrease of the probability of acceptance (Figure 5).

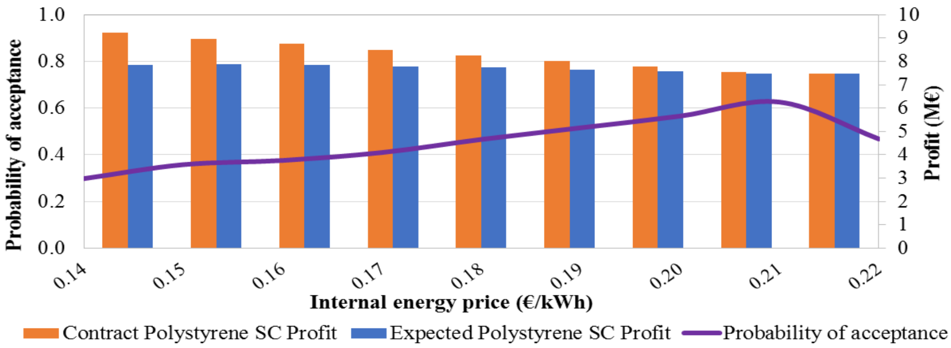

Figure 5- Polystyrene SC contract/expected Profit vs. Probability of acceptance

Table 1 summarizes the expected Polystyrene SC decisions: the total energy amounts needed for the Polystyrene SC is (24.71GWh); at the contract price 0.15€/kWh, it is expected that 36% "probability of acceptance (Figure 5)" of this amount will be supplied from the energy SC (8.84 GWh), while the rest is to be supplied from the local Grid network (15.86GWh). This explains why the expected Polystyrene SC profit at 0.15€/kWh is higher than at contract price 0.14€/kWh, as the probability of acceptance increases.

Table 1- Polystyrene SC contract prices scenarios and expected decisions

Internal energy contract price (€/kWh)	Apparent energy price (€/kWh)	Expected poystyrene Profit (M€)	Expected internal energy (GWh)	Expected internal energy (M€)	Expected energy from Grid (GWh)	Expected energy from Grid (M€)
0.14	0.196	7.86	7.36	1.44	17.34	3.64
0.15	**0.195**	**7.88**	**8.84**	**1.72**	**15.86**	**3.33**
0.16	0.197	7.84	9.29	1.83	15.42	3.24
0.17	0.200	7.77	10.13	2.02	14.58	3.06
0.18	0.201	7.74	11.51	2.32	13.19	2.77
0.19	0.205	7.64	12.75	2.61	11.96	2.51
0.20	0.209	7.56	13.98	2.92	10.72	2.25
0.21	0.214	7.49	15.47	3.31	9.24	1.94
0.22	0.215	7.49	11.56	2.48	13.14	2.76

From the Energy SC side, and based on the contract offer of the polystyrene SC (8.84GWh at contract price 0.15 €/kWh), the resulting Energy SC profit (2.56M€) improves the pre-negotiation Profit by 5%. According to the probability distribution curve (Figure 6), the resulting Energy profit seems to have a high probability of occurrence, in which the Energy SC should accept.

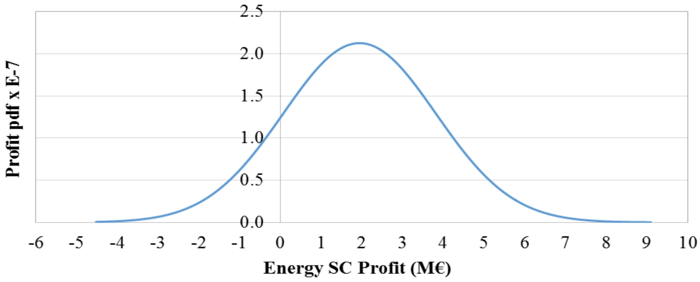

Figure 6- Probability Distribution of the Energy SC Profit

Conclusions

A win-to-win Scenario-Based negotiation approach is proposed for a decentralized multi-site multi-product SC in a highly competitive environment. Under the leading role of one partner SC, different price scenarios are analyzed: i) pre-negotiation scenario, ii) individual objectives-based negotiation (scenario I), and iii) global objective-based negotiation scenario (scenario II), resulting in different MINLP models, which have been used to determine the decisions needed, which maximize the individual/global SCs profits, to fulfill different external requirements. The proposed approach is illustrated using a case study which coordinates different suppliers' SCs (follower) and an industrial production/distribution SC (leader) through a global scenario. A reduction cost of uncertainty is considered when estimating the expected leader SC profit in form of probability of acceptance. The results show that the negotiation scenario (I) based on maximizing individual objectives proves to be the most adequate scenario leading to higher global profits of 8.6% and 3.5% than the pre-negotiation and negotiation scenario II, respectively. The expected leader SC profit is obtained, and the follower SC profit is evaluated using its probability distribution curves. The proposed approach allows to contemplate the different mechanisms a SC may use to modify its relationships with its customers and suppliers during the optimization procedure, which can be used for further second stage agreements.

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