Collaborative lot-sizing in an industrial symbiosis context

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1 Introduction

Industrial symbiosis represents a sustainable way of sharing resources and converting unavoidable production residues into useful and high added-value products. One of the most common beneficial forms of a symbiotic industrial practice is the process by which, by-products of a production unit become raws materials for another one. By definition, by-products are lawful undesirable production outputs, whose further use is sustainable.

Among the abundant number of industrial joint production systems studied in the literature [3], very little consideration has been given to industrial symbiosis networks in the production planning literature. To the best of our knowledge, no paper deals with advanced collaboration policies in an industrial symbiosis framework.

Given the circular economy concerns and industrial needs, let us investigate two advanced collaboration policies in an industrial symbiosis framework for partial information sharing: **(i)** a game-theoretic collaboration policy for one-sided asymmetric information sharing, **(ii)** a contractual-based collaboration policy obtained via a negotiation scheme managed by a blinded mediator, for symmetric information sharing. These collaboration policies for partial information sharing are analysed compared to several baseline centralized and decentralized collaboration policies for full and no information sharing, using mixed-integer linear programming. These collaboration policies are discussed according to three dimensions: the satisfaction of involved actors, the environmental impact and economic benefits.

2 Problem statement

Consider an industrial symbiosis single-item lot-sizing problem (ULS-IS) between two production units PU1 and PU2. Each production unit produces a different product in order to meet its own deterministic demand. PU1 generates a by-product at the same time as its main product. The generated by-product can be: disposed of, sent to PU2 for a unitary cost lower than the unitary disposal cost, or stored with a unitary holding cost. Note that, the by-product inventory is limited by a constant capacity. To supply its production with raw materials, PU2 can choose either to use the by-product generated by PU1 or to order at an external supplier. The unitary cost of buying the by-product is lower than the purchasing cost of raw materials. In addition to the aforementioned costs, the classical costs related to the lot-sizing problems are included in the objective function for each production unit, namely: fixed setup costs, unitary production costs and unitary inventory holding costs of the two main products. The objective function aims at minimizing the sum of all costs of both PU1 and PU2 occurring over the whole planning horizon.

3 Collaboration policies for partial information sharing

Game theoretic-based collaboration policy for one-sided asymmetric information sharing. One-sided asymmetric information sharing means that one actor, called a *leader*, has more information than the other ones, called *followers*. The leader is able to propose a contract and the follower adapts. Regarding partial information sharing, the literature considering a leadership is scarce, in particular, in discrete time space [2, 1]. In an industrial symbiosis network, the leader and the follower aim to collaborate, i.e. to synchronize their production plans in order to reuse the by-product generated by the supplier. For this purpose, the leader proposes a menu of contracts. A contract is composed of a production plan, and a potential side payment, i.e. an amount of money given by the leader to the follower to encourage him/her to accept the contract.

Negotiation scheme managed by a blinded mediator for symmetric feedback. In accordance with the literature about negotiation, let us assume that the mediator knows only non-sensitive information, like the demands and by-product inventory capacity. The goal of the mediator is to propose contracts economically and environmentally attractive for PU1 and PU2. A contract is composed by an exchange plan. To propose good contracts, the mediator has to estimate accurately the unknown parameters. Values of local costs are randomly chosen in intervals. The mediator solves the model with these values. Each PU evaluates the exchange plan and gives feedbacks. The choice of the final contract, as well as collaboration policies, are discussed according to three dimensions: the satisfaction of involved actors, the environmental impact and economic benefits. The two following collaboration policies are compared to several baseline centralized and decentralized collaboration policies for full and no information sharing, using mixed-integer linear programming.

Extensive numerical experiments on a large number of heterogeneous instances show that the game theoretic based collaboration policies provide high environmental benefits at the price of a bad distribution of the gains between the actors, despite the side payments. Regarding the negotiation process, the criteria used to choose the final contract has an impact on the economic and environmental gains but they still are good, i.e. similar to the gains obtained with the collaboration policy for full information sharing. The generation of multiple contracts has the advantage of allowing to favor a non-economic criterion.

References

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